EDISON ELECTRIC INSTITUTE BULLETIN

AUGUST, 1939

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EDISON ELECTRIC INSTITUTE

THE ELECTRIC LIGHT AND POWER INDUSTRY

Current Statistical Data Covering 100 Per Cent of Industry

APRIL AND MAY 1939

	APRIL	MAY
	SOURCE OF ENERGY	
Kilowatthours Generated (Net)		
By Fuel Burning Plants	5,333,396,000	5,939,218,000
By Water Power	4,025,331,000	3,783,277,000
Total Generation	9,358,727,000	9,722,495,000
Net Purchases		
From "Other Sources'	305,904,000	312,492,000
Net International Imports	93,013,000	113,498,000
Total Purchased Power	398,917,000	425,990,000
Total Input	**9,757,644,000**	**10,148,485,000**
	DISPOSAL OF ENERGY	
Total Sales to Ultimate Customers	**8,240,417,000**	**8,282,497,000**
Company Use, Etc.		
Used in Electric Railway Department	27,516,000	25,446,000
Used in Electric and Other Departments	152,314,000	138,944,000
Furnished Free or Exchanged in Kind	5,572,000	4,996,000
Total Company Use, Etc.	185,402,000	169,386,000
Total Energy Accounted For	**8,425,819,000**	**8,451,883,000**
Losses and Unaccounted For	1,331,825,000	1,696,602,000
Total Output (To Check Above **"Input"**)	**9,757,644,000**	**10,148,485,000**
	CLASSIFICATION OF KILOWATTHOUR SALES	
Residential or Domestic	1,699,901,000	1,604,291,000
Rural (Distinct Rural Rates Only)	(Allocated to)	(Allocated to)
Commercial and Industrial		
Small Light and Power (Retail)	1,594,312,000	1,564,010,000
Large Light and Power (Wholesale)	4,109,280,000	4,302,902,000
Public Street and Highway Lighting	133,505,000	121,204,000
Other Public Authorities	192,137,000	193,299,000
Street and Interurban Railways	322,060,000	311,079,000
Electrified Steam Railroads	150,618,000	149,468,000
Interdepartmental	38,604,000	36,244,000
Sales to Ultimate Customers	**8,240,417,000**	**8,282,497,000**
	ESTIMATED REVENUE	
Revenue from Ultimate Customers	$183,833,200	$180,782,500
Other Electric Revenue	2,154,100	2,329,000
Total Revenue	$185,987,300	$183,111,500
	RESIDENTIAL OR DOMESTIC ELECTRIC SERVICE—12 MTHS. ENDED	
	(April 30th)	**(May 31st)**
Kilowatthours per Customer	870	874
Average Annual Bill	$36.28	$36.36
Revenue per Kilowatthour	4.17¢	4.16¢

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EDISON ELECTRIC INSTITUTE BULLETIN

Volume 7 AUGUST, 1939 No. 8

The First 100 Days of the Electric Utilities Exhibits at the New York World's Fair

6,000,000 Visitors to Forward March of America and The Electrified Farm

By Gardner Boyd
Edison Electric Institute

WHEN the New York World's Fair opened its gates on the 30th of April, 1939, the electric utility industry, through Electric Utilities Exhibit Corporation, presented two separate exhibits to the public.

One was designed to give visitors an understanding of the utilities' public service objectives and their contributions to present-day living. The other was planned to show farmers the many ways in which electricity will serve them with profit.

With the Fair approximately half over, the opportunity is afforded to check results and discover how well these exhibits are succeeding in accomplishing the purposes for which they were intended. It is possible today to gain a very satisfactory view of what has happened so far and to draw what should be fairly accurate conclusions as to what the remaining three months of the Fair should accomplish for the utility companies which backed these exhibits and for the industry as a whole.

The daily press has had much to say recently about "poor attendance" at the Fair. This is undoubtedly true in comparison with standards necessary for profitable operation determined by the Fair management in advance of opening. But so far as the Electric Utilities Exhibits are concerned, attendance has not only been excellent from the numerical point of view but from the qualitative aspect as well. The Exhibits management has no fault to find with its attendance.

To August 15, the cumulative total of visitors to the main exhibit—Forward March of America—was 3,125,022. This count was made by guards at the entrance to the exhibit, taking the crowds as they entered. The figure amounts to between 25 and 30 per cent of all paid admissions to the Fair during the hours when Forward March of America is open.

It has not been possible to make a continuous count of visitors to the Electrified Farm. However, spot checks have been made frequently, and these checks compared with attendance at Forward March of America for the same periods. It appears from these comparisons that the Farm draws regularly from 75 to 80 per cent as much attendance as Forward March of America, and that the total attendance at the two exhibits, up to August 15, has been approximately 6,000,000.

This is a large audience for the utility story. Certainly millions of people understand it better today than they ever did before. Furthermore, these people represent the entire country. An examination of names of those who have registered at one or the other of the two exhibits shows that every state in the United States has been represented. Visitors from South America, Australia, Europe, Africa and the Far East have all seen these exhibits and are taking back home with them the story of what the American electric utility industry is doing to contribute to this country's welfare and progress.

At the Farm is an Information Booth to which many visitors turn. Primarily they want to find out more about the various appliances and pieces of electrical equipment demonstrated at the Farm. In order that they may be fully served they are asked to fill out cards giving their name and home address, the appliances on which they want information, and the name of the electric utility company which serves them. Many thousands of these cards have been filled out. The information on the cards is promptly forwarded to the manufacturers and others who contributed material and equipment used on the farm and to the utility companies serving the inquirers named.

At Forward March of America is the Personal Service Bureau, staffed not only to answer questions but to provide a service which will actually be personalized to meet the most varied individual needs. Here requests are received for the special souvenir booklet which Electric Utilities Exhibit Corporation has published —and these requests, too, are made by filling out a special card giving name, home address and the name of the local electric company. To August 15, more than 75,000 of these cards have been filled out, and these, too, are being forwarded to the individual companies whose names they bear.

The Personal Service Bureau also arranges personalized tours at the fairgrounds. These tours consist of a splendid map of the Fair on which a special route is marked out to cover those points in which the visitor is especially inter-

Photo by Damora in U. S. Camera, 1939

Among numerous pictures of the New York World's Fair, published in its World's Fair issue, U. S. Camera, 1939, selected seven for special display. Two of these were shots of Forward March of America. This is one of them showing the waterfall.

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ested. Persons wishing this service apply for it before leaving home through their local electric utility company, which immediately forwards the request to the Utilities Exhibit at the Fair. Thus the visitor, when he enters the fairgrounds, goes first to Forward March of America, where he finds his tour awaiting him. Many thousands of these tours have been supplied.

Among the utilities which have been particularly active in making use of the Personal Tour service are Philadelphia Electric Company, Public Service Electric & Gas Co. of N. J., Virginia Electric & Power Company, West Penn Power Company, Potomac Edison Company, and all companies of the Niagara Hudson System. These utilities are all doing an exceptionally fine job of telling their customers about the Personal Tour Service, and forwarding applications, thus making certain that their customers see the Utilities Exhibits when they reach the Fair. There can be little doubt that these companies will benefit in improved customer relations as their customers get the utility story from the two exhibits.

This Personal Service Bureau of the Utilities Exhibit is truly one of the features of the Fair. Since it is the chief point of personal contact between the Exhibit and visitors, it deserves particular attention here. The staff of five men and three women—all young and college trained—have all had prior experience in sales or promotional work. Their aim is to exemplify to the public that spirit of public service upon which the utility industry rests. They have been so successful in meeting the most varied and unusual requests that the World's Fair Information Service lists the Utilities Personal Service as "willing to do practically anything for you," and depends upon it to handle numerous problems that the World's Fair Information Service itself cannot handle. Since the World's Fair reduced its information staff in the interests of economy, a large amount of additional work has been thrown on the Utilities Personal Service staff, which has welcomed it as additional opportunity to demonstrate its ability and willingness to serve.

Among the regular services which Personal Service performs are providing information about the Utility Exhibits themselves and about other exhibits at the Fair; supplying rooms for visitors—(a headache when people want this service at 10 o'clock Sunday night, just at closing time); arranging for theater, hotel, train and boat reservations; mailing parcels; cashing Travelers Checks; advising people where to go and what to see in New York City; buying baseball tickets; and caring for lost children. Its more unusual tasks have included repairing a broken sandal for its owner, mending a rip in a pair of trousers, and supplying aspirin tablets to headache sufferers.

Even this amazing versatility is balked on occasion. A question as to how to find the Giant Test Tube was only solved when somebody suggested that perhaps what was meant was the Time Capsule, which proved to be correct. Inquiries for the "rowboat" and the "automatic gentleman" both proved to be properly answered when the Westinghouse Robot was suggested. What stumped the staff worst was a question on how to find one particular exhibit which—several days later—was found to be—not at the New York World's Fair—but at San Francisco! The staff admits difficulty with questions like that!

The request which the staff considers its most amazing one came from a zealous and determined woman bearing a pencil and pad of paper who approached one of the young women behind the Information Desk. It became obvious that she was a deaf-mute when she placed the pad on the desk and started the conversation by writing: "Do you demonstrate the electric chair? Would like to see one demonstrated."

Nonplussed but willing, the girl, mentally reviewing the various electrical exhibits, wrote in reply: "Did you see one on exhibit?"

"No," came the written answer; "I mean an ordinary one."

"What is this electric chair used for?" wrote the now completely perplexed young woman, thinking possibly it was something new on the market—perhaps

Clancy the Cop, on the Street of 1892 in Forward March of America

The completely electrically equipped house on the Electrified Farm

an electric rocking chair, for example, or perhaps a chair for therapeutic treatments.

The final straw came with the reply: "Used for executing murderers."

In general, the staff says, people know their utility companies better when the company has publicized its initials as a trade mark. Thus PEPCO and PP&L, and other familiar combinations come to mind instantly when the visitor fills out his card, while people served by companies which do not so emphasize some short form of their names have much more difficulty in recalling the company name. Occasionally a women is seen to take an electric bill from her purse and read her utility's name before filling in the card. Other women protest—"I don't know the name because I don't pay the bills!" Those who do not use utility service—and there have been a few, especially at the Electrified Farm—register embarrassment at having no name to insert.

On the other hand, the staff has become adept at supplying the utility's name as soon as the visitor writes down the name of his city. This seems to please visitors, who apparently like to feel that their local company is so well known that somebody in New York can call it by name. In cases where the directory must be used the visitor is always pleased to find his own town listed in a national directory. A splendid job of building up the local company to its customers is thus being done.

Visitors frequently want to know whether their own company contributed to the cost of constructing the exhibit. Unfortunately this is a question that has to be tactfully handled. No company, however, has suffered from the replies that have been given.

As far as the Forward March of America exhibit itself is concerned, there is plenty of evidence that its story gets across to the public. Designed as a "walk-through" exhibit which people can "read as they run," the attempt has been to emphasize the contrast between the world of today—with electric service—and the world of yesterday without it. The Street of Yesterday depicts a scene familiar to everyone half a century ago. Inevitably it brings nostalgic memories to most of the people old enough to remember those "good old days," while younger folk inspect its store windows, homes and other features with keen interest to see what the world looked like "when Mother was a girl."

The Avenue of Tomorrow, interestingly enough, has developed into what has been called "the best fashion display at the Fair." This is due to Manager Clayton Irwin's foresight in contracting with one of New York's leading Fifth Avenue department stores to arrange the store window displays in the modern street. This store sets up a new exhibit each week. A gentleman who was seen to spend hours in the lounge finally explained that he waited there for his wife, who came regularly every week to see the new fashions! No stronger attraction for women, of course, than a good fashion show.

The lounge, incidentally, attractively furnished with comfortable seats, and looking out through huge portholes beneath the big waterfall which covers one side of the building, is one of the most popular meeting places at the Fair. Air conditioned, it provides a point easily located where people can easily find each other, and be sure of comfortable and attractive surroundings while they wait.

Comments on the exhibits are very numerous. Visitors frequently seem to feel the need of expressing their appreciation to somebody in authority, and Personal Service gets most of these. "You have a *wonderful* exhibit, *especially* the Old Street," is a frequent comment from older people. "You're doing a grand job and getting your story over," comes commonly from the younger group. General reaction, the staff declares, is that the exhibit is "100 per cent satisfactory." Many comments have been written on the applications for the souvenir booklet. More than one has expressed such thoughts as: "Most beautiful exhibit at the Fair," and "A fascinating story effectively told." Most wistful comment is undoubtedly that of a Nashville man who wrote on the line reserved for the name of his utility company: "When I left home it was Tennessee Electric Power Company, but I suppose when I get back there again it will be TVA."

Electric Utilities Exhibit has not attempted to bring in celebrities and then publicize their visits because it desires to maintain an atmosphere of dignity and to avoid the exploitation of personalities as likely to detract from its main objectives. That such people are free to come without attendant publicity was perhaps the thought back of a remark made by one of the leading officials of the Federal Government's power program, who wrote on his card: "A dignified, dramatic treatment of the story."

When Mrs. Roosevelt visited the Farm, to mention it later in her syndicated column, she came "on her own," and went through the area just as any other citizen does, although the young lady who was mixing a cake in the Farm kitchen declares that when she looked up and recognized her visitor through the glass, she "nearly fell into the batter."

Many other distinguished persons have gone through the Exhibits without being subjected to publicizing attentions.

The Personal Service staff has been particularly impressed by the number of utility executives who have returned time and time again for lingering visits to review every portion of the Exhibits. This, they report, was particularly noticeable following the Institute's June Convention, which brought several hundred utility men there for an afternoon. During the remainder of the week dozens of these men came back, usually alone, to visit Forward March of America and the Electrified Farm.

Both Exhibits have had a "good press." From coast to coast newspapers have devoted large amounts of space to the farm, the Street of Yesterday and the Avenue of Tomorrow. Syndicate feature writers have found them popular subjects. Rural papers frequently use such expressions as the following, gleaned from a Southern newspaper: "The Electrified Farm at the World's Fair is certainly one place where our readers who visit the Fair will want to spend some time."

Pictorially the Exhibits are of high rank. The waterfall facade of Forward March of America has frequently been called the most photographed subject at the Fair. Stand around outside the building for five minutes on any sunny day and you'll be convinced that this is so. The grounds are always crowded with amateur photographers pointing their lenses toward the rushing waters. Professional photographers show no less enthusiasm.

The 1939 issue of *U. S. Camera,* devoted to the World's Fair, heads one of its sections as follows: "To say that here are the seven best shots of the Fair would be an injustice to the hundreds of fine photographers who have made excellent negatives on the fairgrounds. Better explanation is that here are seven photographs too good to be used in postcard size—seven photographs kept out of the gallery section only by Time and Space. For five of them, thank Robert Damora, young architectural photographer whose feeling for mass and structural balance can be traced to his architectural schooling." For two of his subjects in this group Mr. Damora selected the Forward March of America waterfall and its Street of Yesterday.

Life has several times published pic-

Light and Glass in "Avenue of Tomorrow," Forward March of America

The last word in modernity in architecture and lighting, this avenue shows the perfect wedding of glass and light. Plate glass, frosted glass, carrara structural glass and glass blocks are used extensively both for the facades of stores and upper floors of the buildings, the tops of which are lost in the night sky.

This Avenue of Tomorrow is more than a strikingly effective street—a contrast for the dim gas-lit era of the nineties, another part of the exhibit. It is also a symbol of the elecric light and power companies' contribution to the fully electrified world of today and tomorrow—the Forward March of America.

tures of the Utilities Exhibits, and *The New Yorker* has found amusing cartoon material at the Electrified Farm. Other magazines by the scores have devoted both picture and editorial space to the two Exhibits.

Radio has found the Exhibits of great interest to their audiences. No special attempt has been made to encourage their interest, yet all the important networks and most of the local New York stations have extended invitations to the Utilities Exhibits to "send over somebody who can broadcast about what you are doing."

The Electrified Farm provides an excellent meeting place for groups in the barn loft. This has been furnished with comfortable seats and other facilities for group meetings. Among the organizations which have used it are Bendix Home Appliances, Inc., which gathered its dealers here prior to its recent prize cruise, Niagara Hudson Power Corporation, which entertained salesmen from its properties here, and Virginia Electric & Power Company, which used the Farm as its headquarters and entertained its friends there during Fredericksburg Day at the Fair.

A group of some sixty editors and writers from Nassau and Suffolk Counties, Long Island, during Farm Week were served a buffet supper at the Electrified Farm by Long Island Lighting System. Edison Electric Institute will holds its Rural Sales Conference at the Farm in September. The space is available to other organizations which may wish to avail themselves of the opportunity to meet in a distinctly rural atmosphere in the midst of the Fair.

Electric Utilities Exhibit Corporation is achieving its objectives in a splendid manner, creditable to the entire industry. If the past rate of attendance is maintained—and there is every reason to believe it will be—the Exhibit will give some 12,000,000 people a new realization of what private capital invested in utility service has meant to the people of this country in making possible the highest standard of living existing in any part of the world.

Add to this impressive number those who are learning the utility service story by radio, newspapers and magazines, all stimulated by the Exhibits themselves, and there is little question but that a substantial proportion of the people of the United States will have a new and inevitably broader perspective on the industry's place in the American economic system.

Federal Control of Electric Utilities

By S. Ferguson
Chairman, Hartford Electric Light Company

A radio talk over Station WTIC, July 20, 1939

FEDERAL control of electric utilities is far too broad a subject to be covered in the few minutes available. I can only briefly touch a few high spots.

Control is being effected, or attempted, by three methods.

One is by direct regulation. As to this I will only say that it is impossible for any Commission located in Washington, to regulate for the whole country with the same degree of success as is accomplished by the Commissions of the various States, each composed of men who know local conditions and the nature of necessary costs in their localities. This is no reflection on the Federal Power Commission but only means that their job is an impossibility because of the widely differing conditions existing in each section of our vast country.

Government ownership is another proposed method of control; this is the objective that is being furthered by all such acts as tend to cripple electric companies. Obviously, if they fail in their obligation to furnish adequate service at reasonable rates, of necessity the Government must step in to serve the public. An example of such acts is the offer of the Federal Government to give outright, 45 per cent of the cost of competing plants and to lend the balance at an extremely low interest rate to enable cities to enter into competition. In the face of the possibility of such competition is it any wonder that private funds seek safer places for investment! And if the companies cannot sell their junior securities they cannot construct the facilities necessary to supply the constantly increasing demand for power.

Another concealed attempt by government ownership advocates in furtherance of this objective of crippling the companies is the effort to persuade the Federal Power Commission to prescribe a system of accounting which must inevitably lead to depriving the utilities of a fair return on their property in the hope of driving them from the field.

The third method is the so-called "Yardstick" by which existing electric rates are attacked by comparisons with by-product operations such as the TVA, subsidized with taxpayers' money. In the few minutes remaining I will cite a few illustrations of the fallaciousness in making such comparisons.

See what is happening in Tennessee! There the private companies are being bought out by the TVA and by the various towns and cities. According to the public statement of Mr. Lilienthal, Director of the TVA, there will be a gain to the users of electricity of approximately $4,000,000 a year. This sounds fine but the Taxpayers' Association of that state is now protesting to Congress that there is going to be a loss of almost exactly this amount, in the taxes now received from the electric companies. These tax receipts of course will disappear and will have to be made up by increased local taxation. Tennessee now realizes the hoax and where the benefits come from, but the rest of the country does not yet understand; and in many places there is agitation for municipal operation at TVA rates without understanding the importance of the prospective tax loss. The TVA is free from all but an insignificant amount of taxation. How important this fact is to its operations can best be judged from what Senator Norris, the Father of the TVA, said the other day on the floor of the Senate.

I quote from his speech:

"A proposal from a great Association of Tennessee says in effect, 'Let the TVA property be subject to taxation the same as everybody's property.' On my desk now there is a printed amendment which provides that all property of the TVA shall be subject to taxation everywhere under the local laws of taxation. If we go to that extreme, Senators can see that the TVA would be out of business in three months."

Of course it would! With such an explicit statement from the Father of the TVA as to the effect of taxes (which is only one of the subsidies) it is fairly clear that the yardstick method of Federal control is an absolute fraud, perpetrated at the expense of the taxpayers of the nation.

We hear in Connecticut the accusation of millions of dollars in overcharge as compared with the Federal yardstick. The reports of the Public Utilities Commission to the Governor completely refute the accusation by showing that if

(*Continued on page* 424)

New Wiring Booklets— "Just What the Doctor Ordered"

A MEASURE of the reception given by the industry to the three new wiring booklets prepared by the Wiring Committee of the Institute, E. A. Brand, chairman, is the fact that a second and larger printing is now on the press. Orders from utility companies for the books exhausted the first printing by the time sample copies of the third book of the series had been placed in the mail.

The booklets, Basic Factors of Adequate Wiring; Covered Neutral Cable Helps Sell Adequate Home Wiring; and Commercial and Industrial Building Rewiring Market, described in last month's BULLETIN, give the results of the years of investigation, research, and trial of new wiring materials and methods, offer practical applications of them, with all necessary technical information, and make a strong and convincing case for their general acceptance. At the same time, the books signal emergence from the research and trial period of the new methods to their active commercial use and provide an effective implement for the aggressive promotion of adequate wiring.

What They Say

From utility executives, wiring authorities, the trade press and from many others have come laudatory comments. Here are a few examples:

"This is really a notable piece of work. It is the best presentation I have ever seen. To take an electrical dealer over the facts and figures presented in these booklets would make him an adequate wiring bug forever. I have never seen the subject so adequately presented."—*An editor.*

"The data presented in these booklets are indeed highly interesting and informative. They should prove useful in the adequate wiring campaign."—*This is from a Department of Commerce official.*

"A complicated subject has been made crystal clear and the magnitude of the savings from the adoption of the code changes recommended by the Institute has been demonstrated in a masterly manner."—*A utility executive.*

"We are enthusiastic about the wiring pamphlets. They are just what the Doctor ordered. At our Sales Conference this fall we are going to urge every operating company in this group to distribute a copy of each of these pamphlets to every electrical contractor and every architect in the territory which they serve."—*Another utility executive.*

Old Styles vs. New

As Basic Factors of Adequate Wiring points out, old style wiring might be likened to a slender elm tree with a small trunk and few branches from this main supply.

Fig. 1—Old Style—Small Service, Few Branch Circuits

The adequate wiring system of today resembles the sturdy oak tree, the trunk representing a large service, substantial limbs representing supply to major utilization equipment, and supply to properly located distribution centers. Plenty of final circuits and outlets are required from these distribution centers to provide for maximum use and convenience.

Basic Factors of Adequate Wiring describes, in readily understandable language, the fundamental requirements for an adequate wiring system and outlines briefly the recent developments in the art which make adequate wiring more economical, both in new and in old buildings. Adequate wiring means ample copper capacity and ample outlets for all the many lamps and appliances which the customer desires to use.

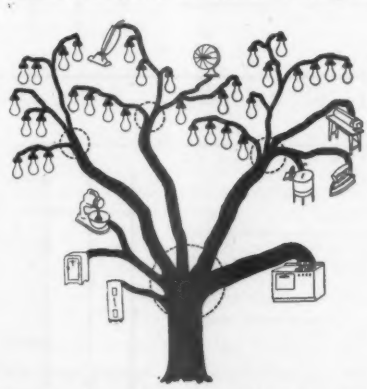


Fig. 2—Adequately Wired—Large Service and Many Branch Circuits

In the Home

Covered Neutral Cable Helps Sell Adequate Home Wiring gives full details on the application of this new type of wiring assembly to small buildings, both residential and commercial. Covered neutral assembly consists essentially of conventional rubber covered wire surrounded by stranded neutral which in turn is covered by heavy paper and then bound together by an outer braid of the type which has proven satisfactory for many years on non-metallic sheath cable. This assembly is made by a number of reliable wire manufacturers and has been extensively tested in the laboratory and used in actual field installations (note Fig. 3).

In territories where this material has been used, enthusiastic reports have been received from contractors, wire men and inspectors.

In Large Buildings

Commercial and Industrial Building Rewiring Market describes the use of the recently developed thin-wall insulation conductors, bare neutral, increased conduit fill, and recircuiting. These various methods can be used singly or in combination, to allow for substantial increase in capacity of existing conduit systems. They involve merely changes in the wires inside the conduit and do not require building destruction and redecoration as would be involved in change of conduit.

By these simple methods capacities can be readily and safely increased two, three, or even more times. A common method of wiring used in the past was to install two circuits of No. 14 in a ½-inch conduit (Fig. 4).

This same conduit can be rewired with six circuits and a total capacity of 12,696 watts by the use of thin wall insulation, bare neutral, and circuit rearrangement.

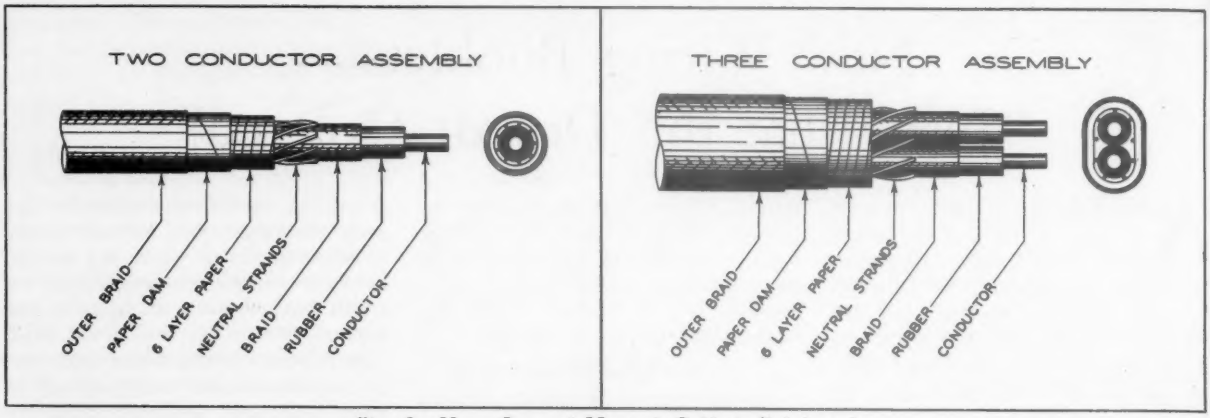


Fig. 3—How Covered Neutral Cable is Fabricated

This particular arrangement provides for balanced circuits and better regulation, either for a three-wire, 115/230 volt circuit, or for a three-phase, four-wire 120/208 volt circuit (Fig. 5).

Many other applications are possible with just as amazing results.

We All Benefit

Everyone will benefit from the promotion and use of these new materials.

THE HOME OWNER AND THE BUILDING OWNER will benefit through adequate wiring at reduced cost per outlet, with equal or greater safety.

ELECTRICAL MANUFACTURERS will benefit despite reduced unit cost. Lower unit cost will encourage fully adequate installations which will not cost less but will provide more for a given cost. The commercial building rewiring market, which is now entirely closed, will prove a most profitable field.

ELECTRICAL WHOLESALERS will profit for the same reason that the manufacturers will profit.

ELECTRICAL CONTRACTORS AND JOURNEYMEN will profit from the increased business resulting from wide use of these new materials.

ELECTRICAL INSPECTORS realize that more adequate wiring reduces circuit overloading, as well as the use of substandard materials for extensions which may not be safe.

COMMERCIAL ESTABLISHMENTS, WHOLESALERS AND MANUFACTURERS will benefit from the increased sale of electrical appliances whose market will be expended when wiring for their use if available.

ELECTRICAL UTILITIES will receive substantial benefit from the use of the materials and methods outlined in these pamphlets. Lower unit wiring costs lead the way for increased capacity and accessibility, and these make it convenient to use more electricity.

The Electrical Code

The new developments described in the booklets have all been presented to the Electrical Committee for consideration in revising the National Electrical Code next December.

Many installations of these new materials have been and are being made with permission of the local inspection authorities having supervision over wiring installations.

These booklets are available on order to the Edison Electric Institute at 420 Lexington Avenue, New York City.

Basic Factors of Adequate Wiring 25c
Covered Neutral Cable Helps Sell Adequate Home Wiring 25c
Commercial and Industrial Building Rewiring Market 35c
The three booklets ordered together.... 60c

Quantity discount—20 per cent for orders of 100 or more copies of each booklet, or 100 or more sets.

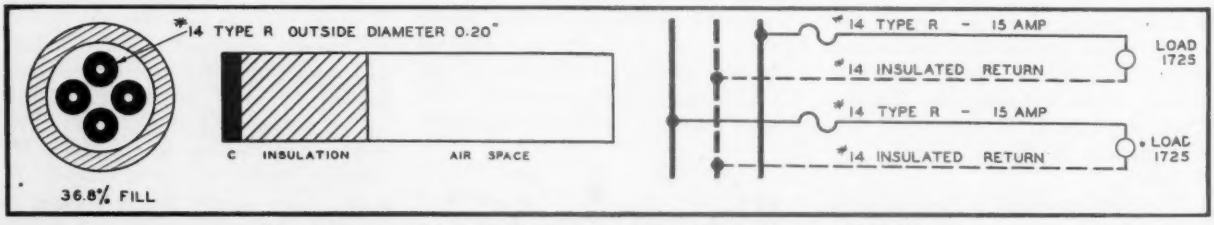


Fig. 4—Former Method—2 Circuits, 4 Type R Conductors 3450 Watts

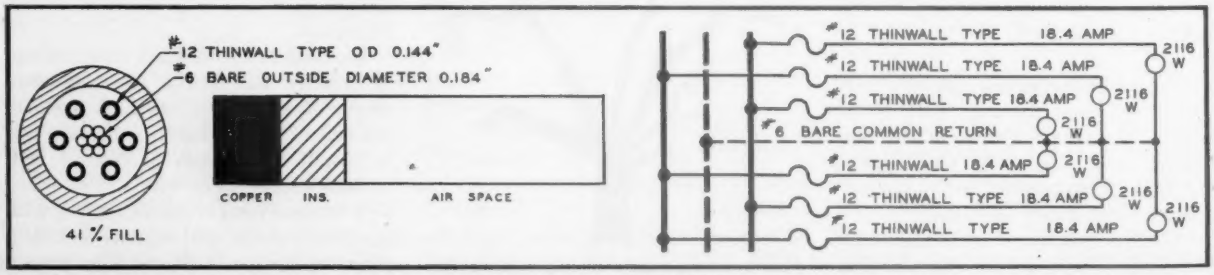

#12 THINWALL TYPE O D 0.144"
#6 BARE OUTSIDE DIAMETER 0.184"
COPPER INS.
AIR SPACE
41 % FILL
#12 THINWALL TYPE 18.4 AMP
#12 THINWALL TYPE 18.4 AMP
#12 THINWALL TYPE 18.4 AMP
#6 BARE COMMON RETURN
#12 THINWALL 18.4 AMP
#12 THINWALL TYPE 18.4 AMP
#12 THINWALL TYPE 18.4 AMP
2116 W

Fig. 5—Proposed Method—Same ½-Inch Conduit Rewired gives 6 Circuits, 7 Conductors, Provides 12,696 Watts Capacity

McGraw Prize Paper

An Effective Load Dividing Device

Simple, Rapid, and Practical Economic Division of Power Generation

By H. H. Johnson and M. S. Umbenhauer

THE economic loading of interconnected power generation facilities has occupied the attention of operating engineers since the first parallel operation of power generators. There has been a constant search for a practical method of finding the economic division of load between two or more sources of power supply under ever-changing conditions.

The result of several years' work by the authors is a device adaptable to economic power division between generating units within a station, between central generating stations, and between generating systems. It offers a means for economic division of electric generation between fuel-burning and hydro plants and also a means for the economic allocation of electric generation and steam supply where a system supplies both forms of energy. Because of its extreme simplicity and easy use the device is invaluable in allocating load economically at the time the load occurs, and, moreover, under the conditions prevailing at that time. This has always been the greatest problem.

To more readily comprehend it, and the solution, a review of some of the problems involved in economic load division will be helpful. This will also serve to show the logical step-by-step development of the device.

Incremental-heat-rates, or incremental-cost-rates, have been accepted universally as the correct basis for economic division of load between sources of energy supply. Webster states that "increment" is "A change . . . in the value of an independent variable; also the corresponding change in the value of the dependent function." According to the incremental rate theory of load division, any increase in the energy output should be supplied by the source having the lowest incremental-heat-rate or incremental-cost-rate. For example, an incremental-cost-rate is the additional cost for a unit increase in energy output. Hence, by always selecting the source having the minimum incremental-cost-rate for the supply of any increase in energy demand, the lowest production cost will be obtained. It will, of course, follow that any decrease in energy demand should be dropped by the source having the maximum incremental-cost-rate.

The selection of which incremental

Mr. Johnson operates their load dividing device while Mr. Umbenhauer watches

This paper won the Second James H. McGraw Prize for 1939. Both Mr. Johnson and Mr. Umbenhauer are employed by the Consolidated Edison Company of New York, Inc.

Mr. Johnson is an Assistant Engineer in the Department Office of the Production Department. He received the degree of Mechanical Engineer from Stevens Institute of Technology in 1925. He was employed in October of that year in the Mechanical Testing Laboratory. From May, 1926 until September, 1928 he was Assistant Switchboard Operator on the High Tension Control Board at Waterside. He was then transferred to the office of the Chief Operating Engineer, where he first served as Junior Engineer and in 1929 as Assistant Engineer. He held this position until May, 1937 when he was transferred to the System Efficiency Bureau. In March, 1939 he was assigned to his present position.

Mr. Umbenhauer is an Engineering Assistant in the System Operation Department. He received the degree of bachelor of science in mechanical engineering from the Alabama Polytechnic Institute in 1928. After graduation he was enrolled in the graduate student training corps of the Westinghouse Electric and Manufacturing Company, East Pittsburgh. In 1929 he was employed by the Brooklyn Edison Company, Inc. as a turbine wiper. He subsequently became an inspector with this company and in 1936 was transferred to his present employment. In 1936 he received an LL.B. from Brooklyn Law School after a course of evening study.

rate to use will depend entirely upon the individual problem at hand. As an example, for the economic division of load between two or more turbo-generators connected to a common steam header the incremental-heat-rates of the turbo-generators would be used. However, if one or more of the units are supplied with steam from a header connected to stoker-fired boilers burning coal, and the remainder of the units are supplied with steam from boilers fired with oil or gas, it becomes necessary to adjust the turbo-generator incremental-heat-rates for the relative fuel costs, to arrive at the incremental-production-costs, which are used in this case. The same would be true in comparing turbo-generators with diesel engine or other internal combustion engine driven generators. The incremental-cost-rate rather than the incremental-heat-rate must also be used in dividing load between two or more stations burning fuels having different costs per heat unit.

It will be recognized at once that the incremental-cost-rates will be a function of the incremental-heat-rates at all times. In the last ten or fifteen years extensive investigation of the incremental rate theory of load division has led to so much excellent material being published that no attempt will be made to demonstrate that incremental-heat-rates are simply calculated values of additional heat input required to carry an extra unit of output. It also has been ably and amply demonstrated that for the purpose of load division between energy sources consuming different priced fuels, the absolute incremental costs are not required, but merely the incremental costs relative to a common base. This means simply that it is not necessary to multiply the incremental-heat-rate by the fuel cost per heat unit, but only by the ratio of the fuel cost per heat unit to the cost per heat unit at some one source of supply—preferably the source with the cheapest fuel cost per heat unit. For example, one unit supplied by steam from stoker-fired boilers using coal costing 18 cents per million Btu, if compared with a unit supplied by pulverized fuel boilers burning coal costing 16.5 cents, may be put on the same base by multiplying the incremental-heat-rate of the unit by the ratio of $\frac{18}{16.5}$ or 1.09

It is apparent, since fuel costs at generating stations vary from month to month, that for lowest over-all production costs, the allocation of loads should change from month to month or at any other time that fuel prices per heat unit change.

Another phase of the problem is the number of possible combinations of generating equipment which can be set up on a system having several generating units. It can be seen at once that the combinations mount rapidly with each additional unit on a multi-unit system. On the larger systems the possible combinations are so great (running into many thousands) that it becomes a hopeless task to predict which combinations of equipment will be run to meet demands, and therefore predetermined schedules of load division between units become inadequate.

Still another aspect of the problem is the variation in the operating characteristics of generating equipment and operating practice from time to time. For example, certain seasonal variations such as the effect of circulating water temperature on the performance of a condensing turbine, or again the effect of make-up water temperature on the quantity of steam bled from a regenerative cycle turbine, etc., call for different distribution of load amongst units for maximum generating economy.

To further clarify the development of this new device for load division it is well to consider the methods in prior use. The most widely accepted means of determining station incremental-heat-rates was the approximate method described in "The Theory of Incremental Rates and Their Practical Application to Load Division" by Steinberg and Smith published in the March and April, 1934, issues of *Electrical Engineering*. Briefly, this consists of establishing separate incremental rates for turbo-generators, for boilers, for electric auxiliaries and for steam auxiliaries, and then combining these by means of a formula. This must be done for each combination of units which will probably be run at a station. It must be borne in mind that the incremental-heat-rate will vary under different operating conditions, such as season, for the same combination of units.

Having established the station incremental-heat-rates, the next step is to adjust them for fuel cost per heat unit. As previously stated, this means multiplying by the relative unit heat price based on some minimum. This produces the station incremental cost curve which next had to be drawn for each combination of units previously determined as probably running simultaneously at the station. Next, the probable combinations to be run at the individual stations had to be combined with the probable combinations to be run simultaneously at the other stations. Then for each of these system station combinations a curve sheet was plotted consisting of replots of the individual station incremental-cost-rates on a common scale and on a common sheet. Station loading schedules were then produced from these sheets by finding incremental-cost-rate ordinates that indicated load allocations between stations at the desired schedule system loads. In order to prepare the schedules required to follow changing system conditions for the vast number of probable combinations to be run on a system of any size, a force too large to be practical would be needed.

The need then was for some means by which the load dispatcher could instantly determine the economical allocation of loads under the system conditions prevailing at the time of the demand.

The first natural step to accomplish this was to resort to logarithmic plotting of incremental-heat-rates for each station combination. Incremental-heat-rate was the ordinate of these plots and load the abscissa. This made it possible to multiply mechanically the incremental-heat-rate curve by the relative fuel unit heat cost. This is accomplished by raising or lowering the curve by an amount proportional to the relative fuel unit heat cost, and does not alter the shape of the curve.

The next step was to make these logarithmic plots of station incremental-heat-rates on a transparent material. It was only necessary to select the combination of units to be run at each station for the proper seasonal and system conditions. These curves were then placed on top of one another, each raised or lowered an amount proportional to its relative fuel unit heat cost. This eliminated the necessity for replotting the station incremental-heat-rate curves each time they were used in combination with a different combination at another station.

Once these curves were set in their proper relative positions they were used by reading the loads indicated on each station on any horizontal line. To facilitate reading, a transparent slider was provided to traverse vertically the stack of curves with a horizontal hair-line. As a further aid the loads were printed at various points on the curve.

Curves, of necessity, had to be on a fairly large scale and would be rather

awkward for a load dispatcher to use, from the viewpoint of both handling and filing.

In order to remove this last objection, narrow paper "loading strips" were substituted for curves. The method of preparation of these strips is illustrated in Fig. 1. The points on the curve corresponding to any desired load values are transferred to the strip by projection. The load values for each point are printed adjacent to the mark corresponding to the point. It may be noted that when the incremental-heat-rate is constant for a range of load that it is only necessary to mark the highest load obtainable at that rate.

It is obvious that the curves were thus compressed into a size and shape suitable for easy handling and convenient filing. Since the strips are narrow, they can be conveniently placed beside one another for comparison. There is therefore no need for having the strips transparent.

It only remained then to build a frame, with slots to hold the strips in their proper relative positions, and to guide the slider. This was done, and a picture of such a device is shown in Fig. 2. The size of the frame will, of course, be dependent upon the size of the scale chosen to represent the incremental-heat-rates logarithmically.

Establishing this scale then becomes the first consideration in building one of these devices. In developing a suitable scale, four factors must be considered: (1) Range of incremental-heat-rates to be covered, (2) the maximum length available for the scale, (3) the width of the divisions on the scale, (4) and finally, the length of scale of the dependent relative fuel cost adjustment scale. A scale was laid out for the device shown, in which load was economically divided between three turbo-generator stations. Their incremental-heat-rates ranged in extremes from about 9000 to 28,000 Btu per hour per kw. Therefore, it was decided that a scale range from 8000 to 30,000 Btu per hour per kw would allow for any reasonably anticipated expansion. To keep the strips from being awkward to handle, their length was limited to 36 inches. For convenience the strips were made 2 inches wide. This allows sufficient room for marking load and also for identification titles at the tops of the strips.

A suitable scale covering the entire range was fitted in a 32-inch length without undue crowding of divisions. This allowed 4 in. at the top of the strips for

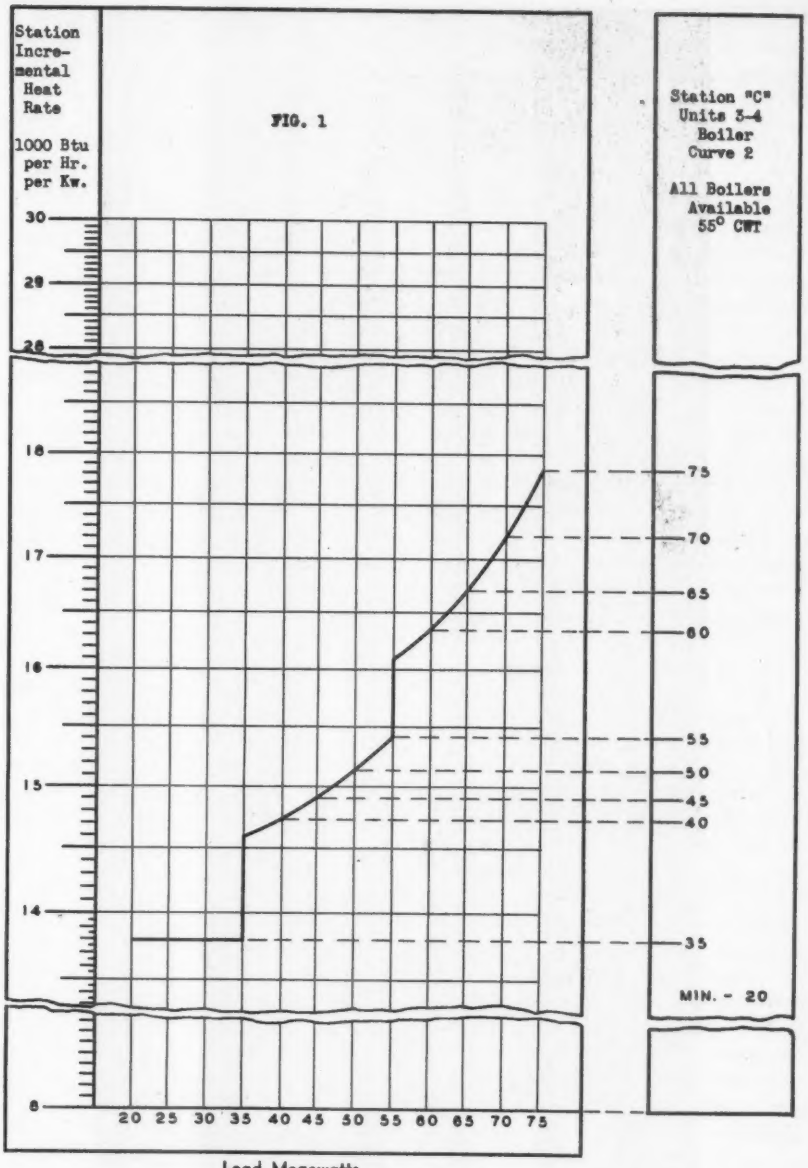


Fig. 1

notations. If it were not possible to include the entire desired incremental-heat-rate range in a required length limitation, the scale would have to be split in two or more sections allowing sufficient overlap of these sections to take care of the fuel cost adjustment. The incremental-heat-rate scale shown was prepared by taking the difference between logarithms of highest and lowest incremental-heat-rates on the scale:

$$\text{Log. } 30{,}000 = 4.4771$$
$$\text{Log. } 8{,}000 = 3.9031$$
$$\text{Diff.} = 0.5740$$

Since this logarithmic difference of 0.5740 was represented by 32 in. on the scale, a difference of 1.0000 in logarithms would be

$$\frac{32 \text{ in.}}{0.5740} = 55.75 \text{ in.}$$

Therefore, with the bottom of the scale representing 8000 Btu per hr per kw, any other incremental-heat-rate is located by multiplying the logarithmic unit division length of 55.75 in. by the difference between the logarithm of the desired incremental-heat-rate and the logarithm of 8000. This gives the number of inches from the bottom of the scale to lay off the desired incremental-heat-rate. These calculations were tabulated as shown in Table I from which the incremental-heat-rate scale was made.

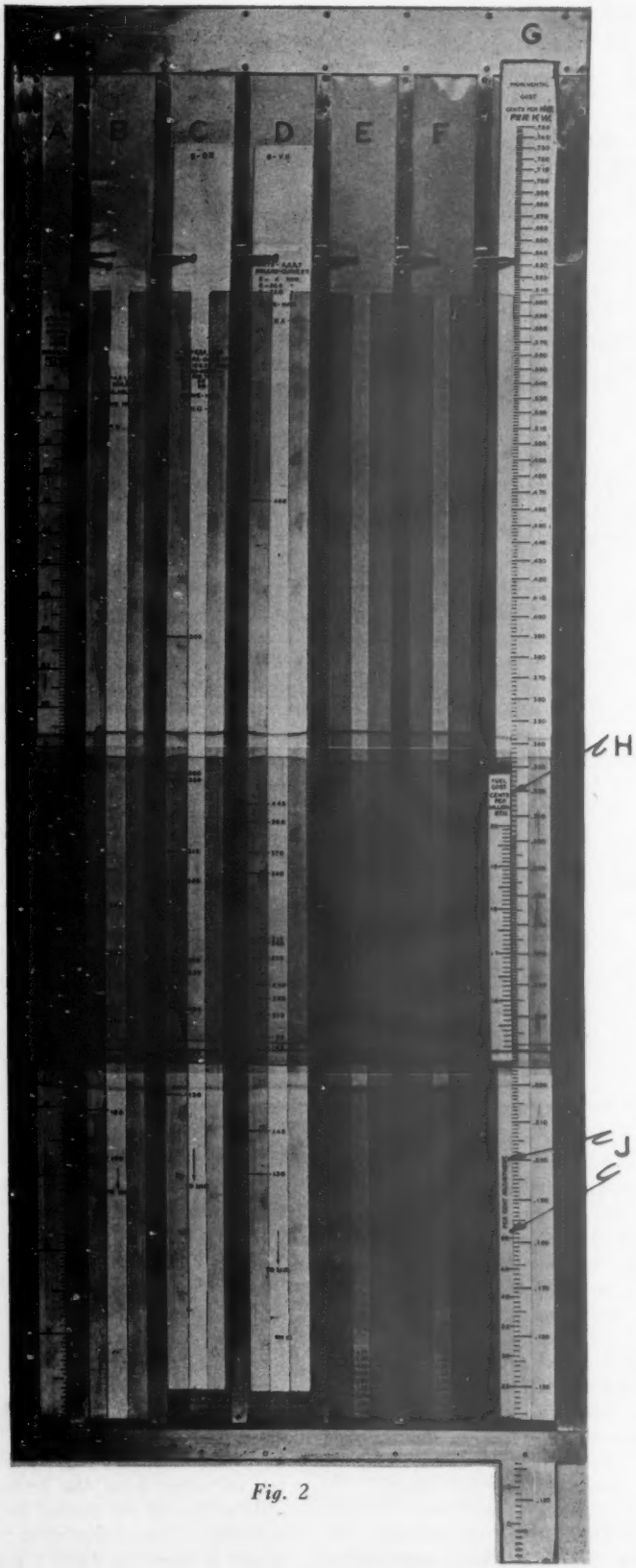


Fig. 2

TABLE I—COMPUTATIONS FOR INCREMENT-RATE SCALE

A Incremental-Heat-Rate Btu per hr per kw	*B Log "A"*	*C Log "A" minus Log 8,000*	*D Inches from Bottom "C" x 55.75 Inches*
8,000	3.9031	0.0000	0.00
8,100	3.9085	0.0054	0.30
8,200	3.9138	0.0107	0.60
8,300	3.9191	0.0160	0.89
....	.....	.....	...
....	.....	.....	...
....	.....	.....	...
29,800	4.4742	0.5711	31.84
29,900	4.4757	0.5726	31.92
30,000	4.4771	0.5740	32.00

In the frame the incremental-heat-rate scale was placed in the left slot as shown at "A" in Fig. 2. The base line of the frame then represents 8000 Btu per hour per kw incremental-heat-rate. From the discussion of the preparation of the "loading strips," it will be recognized that the bottom of each "loading strip" represents an incremental-heat-rate of 8000 Btu per hour per kw.

If the "loading strips," representing different stations having the same fuel unit heat cost, are inserted, they will all be dropped in the slots until their bottoms rest on the base line. The strip shown in slot "B" of Fig. 2 is so placed. However, if one has a higher fuel unit heat cost than the others, its bottom will be raised above the base line by a distance proportional to the ratio of the fuel unit heat costs. Strips thus set are shown in slots "C" and "D" of Fig. 2.

In establishing a fuel cost adjustment scale, the same unit logarithmic distance as that in the incremental-heat-rate scale must be used. In the case cited, this was 55.75 inches, representing a logarithmic distance of 1.0000. Since the frame base line represents a fuel unit heat cost ratio of 1.00 (logarithm 0.0000), to locate any other ratio multiply 55.75 inches by the logarithm of the desired ratio. This gives the distance in inches from the bottom of the scale at which to lay off the desired ratio. The relative fuel cost adjustment scale was developed for each 0.01 covering a ratio range from 1.00 to 1.10, as shown in Table II, from which this scale was made.

This scale is placed at the bottom of each slot and can be seen in slots "E" and "F" in Fig. 2.

The device as thus far described is suitable for economic loading of an isolated system. For interconnected systems involving energy transfer other features must be added.

TABLE II—COMPUTATIONS FOR COAL-ADJUSTMENT SCALE

A *Fuel Cost Ratio*	*B* *Log "A"*	*C* *Inches from Bottom of Scale "B" x 55.75 Inches*
1.00	0.0000	0.00
1.01	0.0043	0.24
1.02	0.0086	0.48
...	.....	...
...	.....	...
...	.....	...
1.09	0.0374	2.09
1.10	0.0414	2.31

In slot "G" of Fig. 2, another scale will be noted. This scale is an incremental-cost-scale. It reads in cents per hour per kw incremental cost. It can be constructed on any fuel cost basis. In the case shown the basis is a fuel cost of 15 cents per million Btu. This is equivalent to 0.000015 cents per Btu.

To develop an incremental-cost-scale for values corresponding to the incremental-heat-rate scale, the incremental-heat-rates are multiplied by the fuel cost, in cents per Btu, selected as base. It will in general be found that this produces a scale which is not divided in even decimals of a cent, and hence is difficult to read. To make a satisfactory scale which reads in even decimal cost values, the location of the costs on the scale must be worked backwards. To do this, divide the desired incremental cost by the fuel cost per Btu. This gives the corresponding incremental-heat-rate which is located relative to the base line from, or as in, Table I, page 11. For example, the scale shown in slot "G" of Fig. 2, page 9, was established with 0.120 cents per hour per kw ($8000 \times 0.000015 = 0.120$) corresponding to the base line of 8000 Btu per hour per kw incremental-heat-rate. The point 0.240 cents per hour per kw corresponds to $\frac{0.240}{0.000015} = 16{,}000$ Btu per hour per kw incremental-heat-rate. This is found in Table I, to be 16.78 inches above the base line. All other points on the scale were similarly located.

With this scale in place the hair-line will always indicate the incremental cost on the basis of 15 cents per million Btu fuel cost. A set of similar scales can be prepared to cover any range of fuel price. The same result can be accomplished more conveniently by adding a supplementary scale to the slider. This is shown as "H" in Fig. 2.

By using this scale the incremental-cost-rate may be read directly on scale "G" for fuel costs other than 15 cents per million Btu. Scale "H" on this device covers a fuel cost range from 15 cents to 20 cents per million Btu. Since scale "G" is a logarithmic function, the divisions on scale "H" representing fuel costs from 15 to 20 cents per million Btu must be made the same as the divisions on scale "G" representing from 0.150 to 0.200 cents per hour per kw. With the hair-line set to any incremental-heat-rate on scale "A," the incremental-fuel-cost may be read directly on scale "G" opposite any fuel cost shown on scale "H."

Further adjustment to scale "G" is provided by the "Per Cent Adjustment Scale" shown at "J" of Fig. 2. This is imprinted directly on scale "G." Often on interconnected systems the pool agreement provides that a percentage of the incremental-fuel-cost be added to the incremental-fuel-cost to allow for additional maintenance, labor, etc. Since this scale is a percentage adjustment or ratio scale, it was constructed in exactly the same manner as the relative fuel cost adjustment scales, as previously described. By setting the desired percentage on scale "J" at the base line, scale "G" will indicate the incremental-fuel-cost plus the added percentage opposite any fuel cost on scale "H."

The device complete with scales and "loading strips" for all combinations of units at each station for the various seasons and operating "set-ups" should be placed convenient for use by the load dispatcher. By means of an index system very little time is needed to find the correct "loading strips" required. The "loading strips" for the conditions prevailing at each station are inserted in the slots with their bottoms set on the relative fuel cost adjustment applicable to the station. In practice, the station having the lowest fuel unit heat cost should be used as the base for the fuel cost adjustment ratio. For economic division of load between stations the dispatcher always reads the loads below the hair-line on the slider from the station "loading strip." If one station cannot meet this economic demand because of some limitation, it should be given as near economic load as possible, and the remainder of the stations loaded as indicated under the hair-line by raising or lowering the slider until the total demand is met. This effectively gives next best economic loading.

To determine the economic interchange of power on systems where pool contracts are involved, the dispatcher has before him at all times the actual incremental costs. By a simple comparison of the incremental costs of the interconnected systems he can easily determine the direction and amount of power flow.

In a system generating more than one form of energy for sale (such as steam and electricity), and having the sources of supply so interconnected that the incremental cost of one is dependent upon the others, then, a separate incremental cost scale is required for each form of energy. By comparison of the costs as indicated by these scales, the economic generation of all energy is determined.

Thus the load dispatcher can have before him a ready means for indicating the economic division of all loads for the system conditions as they exist at the time. It will be seen that, whereas many thousands of schedules would be necessary to meet all system conditions, a few hundred "loading strips" will suffice for even the larger systems.

Beside serving as an economy load divider, this device also makes possible accurate billing for energy interchanged under a pool agreement. The actual incremental value of energy transferred each hour may be determined for the conditions prevailing rather than through the use of average curves. The practice of using incremental cost curves, based on averages, frequently causes an actual loss on power interchange and furthermore often prevents profitable transfers.

It is recognized that in adapting this device to particular systems special problems involving the relationship of the scales arise, but can be solved practically. Detailed discussion of these are omitted here. It is not believed that any of these are incapable of solution by any one having a thorough understanding of the principles involved.

In conclusion, it should be pointed out that the device could have been built from any one of several different designs which were developed. For example, instead of a flat frame, a round drum could be used to hold each station "loading strip." These drums could rotate with respect to one another in order to set off the relative fuel cost ratios. Then they could be clamped together and simultaneously be rotated for load division while the hair-line remained stationary. As another example, holes could be punched in the "loading strips" in

(*Continued on page* 403)

[This advertisement appeared August 13, 1939 in Chattanooga and Nashville, Tennessee, newspapers.]

Tonight, *at Midnight...*

we hand over our Tennessee Electric Properties *and a $2,800,000 Tax Problem*

AT MIDNIGHT, TONIGHT, The Commonwealth & Southern Corporation turns over to various public officials all of its electric properties in the State of Tennessee.

We have always believed, and still believe, that the interests of the public are better served by privately operated utilities than by publicly operated plants. Take our Tennessee properties for example:

The State of Tennessee and most of the communities we have been serving have depended, in no small part, upon the taxes they have collected from us to pay the cost of their governmental activities, including school, water, fire, health and other services.

Our Tennessee properties paid into local and state treasuries a total of $2,225,000 from electric revenues, for the 12 months ended June 30, 1939; with federal taxes, the total for this period is about $2,800,000. That is more than 20 cents out of every dollar received for electric service in Tennessee... it amounts to over $7,670 in taxes for every day of the year.

All of our facilities in Tennessee have been built with the money of many private investors. The communities never had to increase their debts to build plants and distributing systems; they never had to pay out interest on bonds issued for electric service. The savings of thousands of citizens were brought, and would continue to have been brought, into this territory to help produce more industry, more local wealth and more steady jobs.

Our Tennessee operation has long given its customers one of the lowest average residential electric rates in the country... as have our other operations in the North and in the South. Our rate has been reduced steadily to where, at the present time, it is much below the national average.

We have continually helped households to own modern labor-saving and convenience appliances, which have already placed the standard of leisure and living in our Tennessee territory considerably above the average in the country.

As result of our progressive merchandising and low electric rates, the average home in our Tennessee territory used far more electricity last year than was used by the average home in the entire United States.

* * * *

We have had to sell our electric properties and turn over a splendid organization to the Tennessee Valley Authority and other governmental agencies because we could not stay in business and compete with virtually tax-free and heavily subsidized plants.

Incidentally, our taxes have been multiplying and mounting for years. They are an ever increasing problem... a veritable "headache", which other taxpayers can well appreciate. To be rid of any tax worries is, of course, always a relief.

We now turn over to government agencies, for about four-fifths of its real value, one of the finest public utility services in this or any other country... one representing private investments of about a hundred million dollars.

The Commonwealth & Southern System now comprises the following operations:

	Electric Customers*
Michigan	440,314
Illinois	69,338
Indiana	38,229
Ohio	137,749
Pennsylvania	49,697
Alabama	143,363
Georgia	221,461
Florida	17,818
Mississippi	44,012
South Carolina	39,411
	Total 1,141,391

*On July 1, 1939.

Almost all the money we are receiving from this sale will be used to pay back the owners of the outstanding bonds and preferred stocks of The Tennessee Electric Power Company, at 100 cents on the dollar. A substantial percentage of these investors live in Tennessee. The common shareholders, principally The Commonwealth & Southern Corporation, are taking all of the loss.

To buy our properties, the municipalities are selling bonds largely tax-free and TVA is selling Government obligations which, in addition, will be a lien upon the incomes of all of us. These tax-free municipal and federal securities will be owned largely outside Tennessee. As a result, much income which citizens of Tennessee received from our Company will no longer benefit this community.

The incomes from all Tennessee Electric Power securities have, of course, been subject to taxation and have long helped to carry the costs of government. Whenever government takes over a private business, not only does the public lose the benefit of taxes paid directly by the business but also the substantial taxes paid by the owners of its securities.

* * * *

We sincerely hope that our former customers in this territory will continue to enjoy one of the best electrical services in the country.

To numerous friends and associates in Tennessee, many of whom have been most helpful and considerate, we are deeply indebted and very grateful. We wish them every success. Our hope is they will never be required to defend a business of their own against government subsidized competition.

Wendell L. Willkie, PRESIDENT

The Commonwealth & Southern Corporation

Farewell newspaper advertisement to customers of the former Tennessee Electric Power Company

Sale of Tennessee Electric Power Company is Completed

SALE of the Tennessee Electric Power Company, operating subsidiary of the Commonwealth and Southern Corporation, to the Tennessee Valley Authority and more than thirty municipalities and rural cooperatives in the State was completed August 15 with the payment of $78,600,000 for the properties by the public authorities and the formal transfer of title.

The sale represented at least a partial victory for public ownership protagonists, backed by the strength of the present Federal Administration, at the same time marking a personal triumph for Wendell L. Willkie, President of the Commonwealth and Southern Corporation, in securing a price that enables the parent company to make full payment on all bonds and preferred stock, and partial payment on common stock. More than 250 representatives of the principals in the transactions, most of them from Tennessee, witnessed the transfer, which was presided over by Mr. Willkie and held in the First National Bank Building in New York. With a few relatively small exceptions the purchase of the company practically eliminates private utility operations in the state, expands the market for TVA power, and culminates more than five years of litigation, debate and consultation between the contracting parties.

In statements released after the closing, Mr. Willkie declared that by the purchase of the properties the Federal Government had acquired, at about 80 per cent of its real value, one of the "best electrical services in the world."

Mr. Willkie's statement was as follows:

"I sincerely hope that our former customers in the State of Tennessee will continue to enjoy the benefits which the Tennessee Electric Power Company originally made possible. Whether or not the quality of service is maintained, these customers will, of course, enjoy the lower rates made possible by government subsidy—but they and all the people in the United States will pay the higher taxes which tax exempt and heavily subsidized government operations inevitably require.

"We sell these properties with regret. We have been forced to do so because we could not stay in business against this subsidized government competition.

"The Tennessee Electric Power Company was started thirty-five years ago by a Chattanooga engineer who refused to believe that the Tennessee River could not be dammed. Since then thousands of employees and many thousands of investors from different states have participated in the remarkable development of this project. It has never received any gifts from the United States Treasury or from the PWA or from the municipalities. On the contrary, it has made substantial tax payments to the Federal and local governments amounting to over $25,000,000 in the last ten years.

"From now on, this business is in the hands of governmental agencies. The participation of private management and private investment is at an end. Another business is removed from the tax rolls. While this sale does not represent the true value of this investment, at least we have received enough to make full payment to the owners of the bonds and preferred stocks. The common stockholders, principally the Commonwealth & Southern Corporation, are taking all of the loss.

"But the loss of these properties will not be in vain if it serves to arouse the American people against government invasion of their business. In looking to the future, I plead with the government for two principles, both of which are essential if the system of free economic enterprise is to be preserved.

"I ask first, as I have asked many times before, that the government discontinue its competition with private business outside the Tennessee Valley. It now has its 'yardstick' area. It should be content with that, so that in other areas of this nation the utility industry may make its vital contribution to American business recovery.

"Second, I ask that these government agencies should keep their books on a completely honest basis, so as not to mislead the American people, from whom these commissions get their power. Not only should these agencies observe the rules laid down by the government for the utilities themselves, but they should make due allowance for such things as the tax income loss to the Federal and local governments whenever a private enterprise is destroyed."

Although some officials, including Gov. Prentice E. Cooper of Tennessee, and David E. Lilienthal, TVA director, hailed the event as a "happy and significant" occasion for the people of Tennessee, numerous municipal representatives paid high tribute to Mr. Willkie and Commonwealth and Southern Corp. and several expressed regret that private operation of electric facilities in their communities was at an end.

Thomas L. Cummings, Mayor of Nashville, said "Tennessee Electric Power Company has given us good service, and I hope the people, under public control, will receive as good service as Mr. Willkie has given us."

Edward D. Baas, Mayor of Chattanooga, said "No community was ever served by a better public utility than we were; Mr. Willkie and his organization have done a great job."

Representative Joseph W. Byrns, Jr. of Tennessee, greeted the assembly and said, "Mr. Willkie has been a friendly enemy of whom we have the highest respect."

L. J. Wilhoit, chairman of the Chattanooga Power Board, who played an important role in the negotiations, said that "the splendid service rendered by Tennessee Electric Power, coupled with the aggressive straight-shooting leadership of Mr. Willkie, created a background for public acceptance of the principle that security holders should be protected in any transaction involving the transfer of any property to public ownership."

News from the Modern Kitchen Bureau

PLANS for The Modern Kitchen Bureau's fall promotion of electric ranges centers around a National Electric Range Exposition in which utilities and dealers everywhere may participate by conducting their own electric range expositions locally. The Bureau has prepared a wide variety of helpful promotional materials for use in connection with these local activities. All of it has been designed so that utility or dealer will be effectively tied in with the national program.

The Bureau's new Plan Book for the National Electric Range Exposition offers valuable suggestions as to how to prepare for the local range exposition. It recommends the use of receipted electric bills borrowed from customers who own electric ranges, so that prospects may see for themselves how little the use of an electric range actually costs. It also points to the need for demonstrating the speed of the modern electric range and suggests that at least one range be kept connected to an electric circuit for this purpose.

Folders for direct mail use, which may carry the dealer or utility imprint, and sales training booklets for the use of salesmen are also included.

Thirty-inch window banners are available which tell all who see them that here in the store displaying the banner is a part of the National Electric Range Exposition to which they are invited. There is also a series of 24-inch arrows, which can be strung up from the entrance of the store to lead customers directly to the range exhibits. Also available is an excellent series of newspaper advertisements, in mat form, which will further identify the dealer or utility with the nation-wide exposition program through his local newspaper pages. There is special material for use on local radio stations.

HOUSEWIVES AMERICA-OVER
ARE READING TODAY ABOUT
ELECTRIC COOKING
HURRY, HURRY, HURRY
American women are not yet fully aware that clean, safe ELECTRIC COOKING is really fast and cheap!
THE TICKET!
"We're Changing TO CLEAN, SAFE ELECTRIC COOKING
NOW IT'S FAST
...AND CHEAP!
ELECTRIC RANGE EXPOSITION

Two pages from the Modern Kitchen Bureau plan book for the autumn National Electric Range Exposition

For its fall electric water heating promotion the Bureau has prepared a campaign program entitled "Time to Change." The groundwork for this program will be national advertising in the September, October and November issues of *Better Homes and Gardens*. Utilities and dealers will capitalize on this with their own window displays, using customers' electric bills as in the range campaign, putting up banners, sending out direct mail leaflets, supplying salesmen with the Bureau's water heating sales training booklet and its new Visual Manual of Electric Water Heating, and developing the best possible prospect list in their own communities. The Bureau makes available materials for this and also a series of advertising mats for local newspaper use.

Included in the program are two important contests, one for utilities and dealers and the other for their salesmen. The first is a window display contest, in which it is necessary merely to submit a photograph of an electric water heater window display set up between July 1 and December 31 of this year. Prizes are $100, $50, and ten of $10 each. Salesmen will compete in the series of contests for the best letter on "How I Sell Electric Water Heaters." The next contest closes September 30, and the final contest ends December 31. Prizes in each contest are $25, $15, $10 and five prizes of $5 each, with a grand prize of $100 for the year's best letter.

Utility executives are also reminded of the Bureau's Utility Contest for the National Electric Water Heating Award given for the best all-around water heating job each year. This contest continues throughout 1939. A cash prize of $1,000 and a silver trophy will go to the winner of this contest.

Winner in the Bureau's second quarterly contest for electric water heater salesmen which closed on June 30 was A. A. Anderson, Pacific Gas & Electric Company, Dinuba, California. Mr. Anderson's letter on "How I Sell Electric Water Heaters" took the first award of $25. In second place was V. Motz, of Wolf & Dessauer, electrical dealers of Fort Wayne, Indiana. Miss Willard Powers, Duke Power Company, Rutherford, North Carolina, took third prize, the first time that a woman has been

(*Continued on page 424*)

Here is the three-foot window banner that dealers will use to announce their participation in The Modern Kitchen Bureau's "Time to Change" Fall Campaign for Electric Water Heating.

Management and Public Relations

By Leonard Lathrop
Jersey Central Power & Light Company

ETERNAL vigilance is the price of peace in the utility business. On one hand, supposedly, sits the customer, warm, comfortable in his surroundings, and smugly preoccupied by his own problems, views, and distractions. On the other hand sits management, in plush seats, sedately reserved, and harassed by grave technical, social, and economic concerns.

Between them are great restless forces, the pressure of scientific advance, new industrial conceptions, social change, propaganda and stepped-up selling methods, politics, associations and leagues, price considerations, and countless other schisms and "isms," all difficult for the individual mentality to coordinate and assimilate.

But together the customer and management form the two poles of a "system," each dependent upon the other to complete the circuit, no matter how widely separated from the standpoint of distribution, thought, or purpose.

To suppose, however, that this basic relationship and interdependence implies a mutual interest and enthusiasm between customer and company, is a Victorian fondness carried over from the days when business was a small and individual thing.

The customer today is fickle, and so is his dollar. Far from holding a monopoly, the utility, in competition for its share of the customer dollar and customer attention, has to get in and scramble like everybody else, or be left at the switch.

To believe, therefore, that the dollar spent for electricity is a stable source of revenue without constant sales effort is another wishful thought destined to bring about a rude awakening when some other and more enterprising manufacturer begins selling service in more interesting and attractive packages.

So to hope for "understanding" and "loyalty" as substitutes for a more active form of public relations and sales promotion are fallacies which, in some instances, have carried the utility industry across pretty thin ice.

The sooner management gets out into the open, therefore, and sets a standard for aggressiveness and progressiveness, the better chance the "system" has of functioning as a unity in meeting the problems affecting the business.

MR. LATHROP

Management's Position

The president of a utility occupies a unique position in the area served by his company. He heads probably the most widely distributed business in the state and employs the most diversified types of labor. His company is a depositor in many banks, a large purchaser of materials and supplies, and has one of the largest investments in plant and property. The company is also one of the heaviest taxpayers, both locally and nationally, and stands to benefit or lose probably more than any other business as a consequence of legislation, national, state, or municipal. In fact, about one out of every 10 pieces of legislation introduced has a definite bearing upon the utility business, and an ultimate effect upon the relationship between the industry and the public.

It is important, therefore, that management take a bold position, both in good and bad legislation, so that minorities may not become the 4-inch tails which wag the dog in legislation affecting both the company and the public.

This policy on the part of management requires vision and clarity of thought, but it also requires expression, as that is the only way in which the views of the management may be translated to the rank and file of employees, many of whom have no way of knowing what the management is thinking.

The wish that government would ultimately let business alone has for a long time been the father to management's thought in dealing with the matter, and it has only been recently that the utility industry has taken the time and trouble to let its employees and the public know how some forms of legislation are affecting the business.

Utility management, in its various stages, has been controlled by engineers, lawyers, or financiers, but in the highly competitive field of today, the utility executive must not only shoulder the burdens of his predecessors, but must possess a vigilant promotional faculty as well if he hopes to keep his business moving on all fronts.

Thus management must be eternally watchful, not only in the development of the system itself, but also in respect to outside influences and conditions which affect the business.

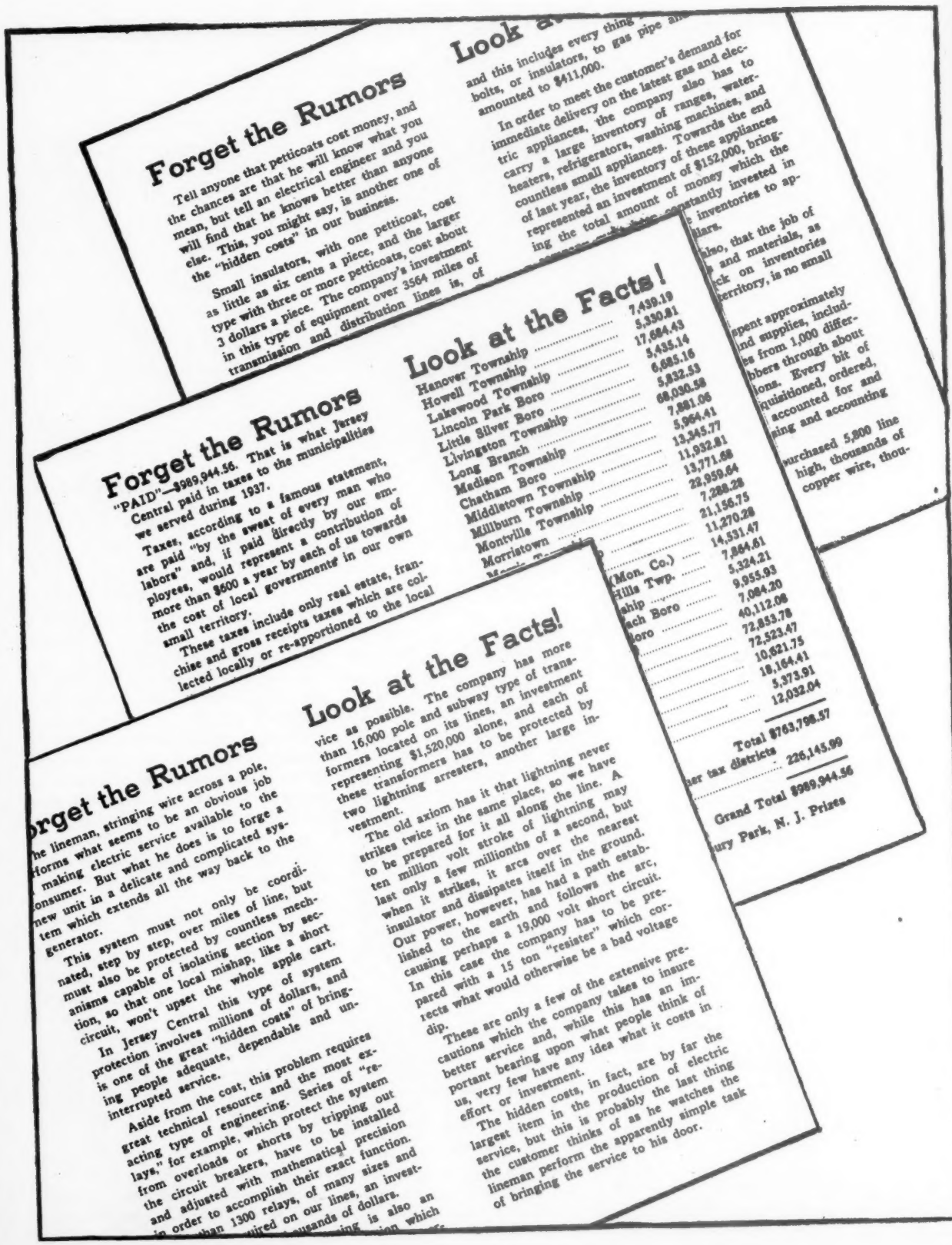
Employee Relations

The character of management is the greatest asset in business, and readily translates itself to the employee, into service, and to the public at large. This is the point at which public relations must begin.

Thought must be given to public relations as a company activity and company policy, however, and time and money invested in carrying a program out. Unless this is done the employee in the corporation of even moderate size will be found to be woefully ignorant or misinformed about his own business and his own organization.

Until recently many executives have held the view that the less said, the better. This has been partly due to a fear of employee movements, partly because of the belief that money thus invested could not be justified on the basis of tangible returns, partly because management was afraid to lay itself open to the charge of "undue influence," and partly because of the lack of qualified people within the organization to handle the specialized side of this work. But it has been due principally to the fact that no thought whatever was given to it.

Management is beginning to learn, however, that Priscilla's admonition to John Alden was pretty good advice. The methods used, of course, vary, but unless



Forget the Rumors

Tell anyone that petticoats cost money, and the chances are that he will know what you mean, but tell an electrical engineer and you will find that he knows better than anyone else. This, you might say, is another one of the "hidden costs" in our business.

Small insulators, with one petticoat, cost as little as six cents a piece, and the larger type with three or more petticoats, cost about 3 dollars a piece. The company's investment in this type of equipment over 3564 miles of transmission and distribution lines is, of

Look a

and this includes every thing
bolts, or insulators, to gas pipe an
amounted to $411,000.

In order to meet the customer's demand for immediate delivery on the latest gas and electric appliances, the company also has to carry a large inventory of ranges, water-heaters, refrigerators, washing machines, and countless small appliances. Towards the end of last year, the inventory of these appliances represented an investment of $152,000, bring-
ing the total amount of money which the
constantly invested in
inventories to ap-
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accounted for and
ing and accounting

urchased 5,800 line
high, thousands of
copper wire, thou-

Forget the Rumors

"PAID"—$989,944.56. That is what Jersey Central paid in taxes to the municipalities we served during 1937.

Taxes, according to a famous statement, are paid "by the sweat of every man who labors" and, if paid directly by our employees, would represent a contribution of more than $600 a year by each of us towards the cost of local governments in our own small territory.

These taxes include only real estate, franchise and gross receipts taxes which are collected locally or re-apportioned to the local

Look at the Facts!

Hanover Township	7,439.19
Howell Township	5,330.81
Lakewood Township	17,684.43
Lincoln Park Boro	5,435.14
Little Silver Boro	6,685.16
Livingston Township	5,832.53
Long Branch	68,030.58
Madison Township	7,881.06
Chatham Boro	5,964.41
Middletown Township	13,345.77
Millburn Township	11,932.81
Montville Township	13,771.68
Morristown	23,959.64
	7,288.28
(Mon. Co.)	21,156.75
Hills Twp.	11,270.28
ship	14,531.47
ach Boro	7,864.61
boro	5,324.21
	9,955.93
	7,084.20
	40,112.08
	72,853.78
	72,523.47
	10,821.75
	18,164.41
	5,373.91
	12,032.04
Total	$763,798.57
ser tax districts	226,145.99
Grand Total	$989,944.56

ury Park, N. J. Prizes

rget the Rumors

he lineman, stringing wire across a pole, rforms what seems to be an obvious job making electric service available to the consumer. But what he does is to forge a new unit in a delicate and complicated system which extends all the way back to the generator.

This system must not only be coordinated, step by step, over miles of line, but must also be protected by countless mechaniams capable of isolating section by section, so that one local mishap, like a short circuit, won't upset the whole apple cart.

In Jersey Central this type of system protection involves millions of dollars, and is one of the great "hidden costs" of bringing people adequate, dependable and uninterrupted service.

Aside from the cost, this problem requires great technical resource and the most exacting type of engineering. Series of "relays," for example, which protect the system from overloads or shorts by tripping out the circuit breakers, have to be installed and adjusted with mathematical precision in order to accomplish their exact function. n than 1300 relays, of many sizes and uired on our lines, an invest- usands of dollars. ing is also an ion which

Look at the Facts!

vice as possible. The company has more than 16,000 pole and subway type of transformers located on its lines, an investment representing $1,520,000 alone, and each of these transformers has to be protected by two lightning arresters, another large investment.

The old axiom has it that lightning never strikes twice in the same place, so we have to be prepared for it all along the line. A ten million volt stroke of lightning may last only a few millionths of a second, but when it strikes, it arcs over the nearest insulator and dissipates itself in the ground. Our power, however, has had a path established to the earth and follows the arc, causing perhaps a 19,000 volt short circuit. In this case the company has to be prepared with a 15 ton "resister" which corrects what would otherwise be a bad voltage dip.

These are only a few of the extensive precautions which the company takes to insure better service and, while this has an important bearing upon what people think of us, very few have any idea what it costs in effort or investment.

The hidden costs, in fact, are by far the largest item in the production of electric service, but this is probably the last thing the customer thinks of as he watches the lineman perform the apparently simple task of bringing the service to his door.

Covers of three of a series of "Forget the Rumors—Look at the Facts" envelope enclosures of the Jersey Central Power & Light Company. Inside pages of the folders are shown opposite

a well thought out and sustained plan of employee education is adopted, management loses an important opportunity

Regardless of method, two basic principles should form the foundation of such a program. The first is that though the views of management and employee may differ because of different perspectives, management should make a real and honest effort to express its own view, rather than to attempt to express views which it merely believes the employees would like to hear.

The second is that in the dissemination of information reliance should be placed upon facts and upon the intrinsic value of the information, rather than upon an abbreviated and spectacular form of presentation.

The full information must be there, should the employee care to absorb it, as this gives him a tangible basis upon which to form his own views, and a real fund of knowledge, if he wishes to study and make use of it.

The Company Publication

The company publication, therefore, which depicts the business, its operation and problems, rather than concern itself solely with personalites, performs a better service, both from the standpoint of management and the employee, than the bulletin of the strictly news type.

The company magazine is, of course, in competition with all other printed matter for reader interest and attention, and consideration must be given to its attractiveness, picture interest, layout and design. But unless the editorial content is of a worthwhile nature, the principal feature of the magazine as a specialized medium is lost.

In this connection it should be pointed out that there are many magazines designed for special readers, such as the trade and professional journals. The utility management, likewise, needs a special medium in order to give full expression and interpretation to its views, for management alone is in a position to present the whole picture of the business.

On the other side, every employee is, or should be interested in knowing how to do his job better, and in this effort he must have help and support directly from the management, for the business is progressing fast and the employee must progress with it.

Other Methods

While the company magazine fills a definite need in most organizations, other forms of printed matter are also important, and a good method of reaching the employee is through enclosures with his pay check.

This affords management an opportunity to present facts pertinent to the business from week to week. Proof that the employees make use of this material in dealing with new problems which may come up in the course of their work has been demonstrated many times where this plan has been used. The subject matter should reach into every phase of the business, and into every department so that, aside from having general application, each folder will have a particular application to certain groups or departments.

Broad welfare policies, employee training courses, wages, hours and many other programs affecting the employee are also important considerations, but more important than anything else is the attitude of management. For only by vigilance and directed effort on the part of management, and a proper presentation of the facts, can rumor, agitation, and dissention be combated.

Management, therefore, must cast aside its reserve and play an active and aggressive role in formulation not only of company policies, but of company opinion.

The customer, on the other hand, who spends a part of his dollar for electric service, rarely stops to think about the technical, economic, and social ramifications of so simple an act. In fact, to him it might almost appear as though the public utility labors, and brings forth a mouse.

In the abstract the fact that what he pays for electric service buys coal, equipment, materials, labor, human welfare and provides taxes does not concern him as much as it should, but he is interested in what electricity costs, and what it will do for him.

This curiosity about cost should be encouraged because the time is coming when the purchaser is going to have to look his dollar squarely in the face and make up his mind just what, and how much he can do with it.

Many utilities at the present time are attempting to stress the value of electric service on a price appeal basis. This takes the form of promotional matter and advertising telling how much can be accomplished electrically for a few pennies, and also the fact that while other living costs have been going up, electric rates have been steadily going down.

The time may not be far distant, however, when the drop in the rate curve will strike bottom, as manufacturing costs continue to rise. So, while the public may not give much thought to the matter now, it must ultimately determine how much may justifiably be paid out of the dollar to maintain the new social and political order through taxation and other levies.

The consumer, therefore, should not be encouraged to believe that rates are destined to go down forever. This, again, is a subject upon which management and customer necessarily differ in view, because while the customer's interest is immediate, especially where price is concerned, the management must look to the future and protect the development of the system by adequate reserves.

This in the long run is, of course, to the interest of the public, as well as the company, and it is management's job to maintain its position in this respect, whether it receives thanks for it or not. Otherwise, agitation for continually lower rates may ultimately defeat its own purpose by seriously impairing the utility's resources and service.

It must be borne in mind, also, that the cost of government and social experiment are spreading out through the economic system and may ultimately absorb such a large part of the cost of living that purchasing power in other directions may be curtailed, and living standards correspondingly lowered.

Business management is face to face with these problems and, because it is organized and has the facilities for the distribution of information, should present its side of the business picture consistently to the public. This is a slow process, especially because of the competition for reader attention, but headway is being made by companies making such an effort.

The head of the house, sitting in the warmth and security of his home, may be bored with the modern hullabaloo and a hard person to reach. He is attracted, nevertheless, by what things cost, and in the case of electricity, what it will do for him. So is the woman of the home.

Literature planned to make this appeal, therefore, should be designed to reach both the masculine and feminine mind, and may be both institutional and promotional in character at the same time.

At any rate, the business side of the economic story must be told if business hopes to hold its own in the war of words today, and management must be vigilant, direct and forceful in charting its course. The "plush seat" day is over and management must step out and meet the public, by personal appearance, through the newspapers, the radio, and the countless other media of the day, for people are forming ideas and forming them fast.

New Business

There is no better way of demonstrating what electricity can do than by putting new appliances in the customer's home. The modern all-electric home exceeds our fondest dreams of ten years ago, and the man or woman who lives in one is not usually the customer who complains about his bills.

In the past few years developments in the manufacture of equipment and along the lines of efficiency in operation have worked miracles in the up-to-date home, and a revolution in living is taking place.

Not until the customer actually experiences the convenience of automatic hot water, electric cookery, or good light, however, can he really become wedded to electric service, and the flow of these goods today is backed up chiefly because of the diffidence of the utilities in wooing the consuming public.

The management, however, which fails to conduct the new business side of the company activity along aggressive and modern selling lines, misses a big point in public relations because the satisfied user is certainly the best advertiser.

It is where this selling policy is lacking that the customer begins to grow fickle, allowing his dollar and attention to be courted in other directions. In this respect, certainly, the traditional tables are turned, because it is the customer who has the monopoly on the dollar, while big business has to join the rest of the small fry trying to get a look at it. So the salesman, or home service girl, who gets in the door is doing the company a real service, whether he makes that sale or not.

Consequently, again in the selling field, management must come out into the open and cast its lot in the competitive market, setting an aggressive standard for the buying public, not the least among which are its own employees.

The promotionally minded employee, furthermore, is the best type of agent for his organization, and his viewpoint along these lines is largely determined by the extent to which the management itself goes in this direction.

To be content, therefore, with the view that electricity occupies a unique and necessary place in the home, enjoying a certain immunity from social and economic vicissitudes, is pure sentimentality and the beginning of decay.

The part which electricity is destined to play in modern living has scarcely begun, and only a disjointed economic system, a break down in the standard of living, or a radical change in the value of money, can retard the development which is on its way.

Back to Our Seats

So let us now go back to our seats, the customer to his home, which is his castle, and management to its little sphere of influence behind closed doors. What, or where, is the point of contact through which these two poles of thought can be fused into an energized "system"?

That point is the attitude of management, for management is the active agent in the business relationship, and management holds the responsibility for the system, for its personnel, and for the type of service rendered.

The character of management is still the great asset of business, and readily translates itself to the employee into service, and to the public at large.

In the end it is not the customer, not the politician, not labor, and not science which hold the key to the future, but the ability of management to meet the rapid changes in the conditions of business, and in this task, indeed, eternal vigilance is the price of peace.

Inductive Coordination of Rural Power and Telephone Lines

The Problem is Location, Design, Operation and Maintenance of the Two Types of Systems so as to Result in the Best Service of Both at the Least Overall Cost to the Public

By H. R. Huntley and J. O'R. Coleman

Respectively, Engineer, American Telephone & Telegraph Company; Engineer, Edison Electric Institute

THE widespread interest at the present time in the inductive coordination of long, lightly-loaded open-wire power distribution systems and telephone systems of the type frequently used for supplying service in rural areas, warrants a review of some of the facts which have been developed through the joint work of the Edison Electric Institute and the Bell Telephone System.

Considerable data on this subject have been published in one form or another and this article summarizes some of them and discusses their significance in a non-mathematical manner.

Reiteration of a few fundamentals is pertinent to the present subject.

(1) It is theoretically possible to build power systems which will have negligible inductive effects on neighboring telephone systems of any type.

(2) It is theoretically possible to build telephone systems which will be unaffected by neighboring power systems of any type.

(3) Even though it might be possible to reach the theoretical conditions of (1) or (2), this is, of course, ordinarily impracticable. Within the limits of practical considerations, the total cost of the telephone and power services to the public will be less when the inductive influence (ability to affect neighboring telephone lines) of the power system is kept as low as practicable and the susceptiveness (ability to be affected by neighboring power systems) of the telephone system is kept as low as practicable, and the two systems are "coordinated."

The problem of inductive coordination is, therefore, the intensely practical one of so locating, designing, operating and maintaining the two types of systems as to result in the best service of both types at the least overall cost to the public.

The first thing which occurs in connection with coordination is the location of power and telephone lines. When considering long distance telephone lines and major power transmission lines, it is frequently practicable to plan substantial separations so as to limit inductive problems—although this is becoming increasingly difficult and expensive in many situations. Consequently, more and more reliance is necessarily being placed on other coordinative measures.

When it comes to power and telephone distribution systems, it is, in many cases, impracticable to avoid having the lines on the same highways because the customers of both services usually are the same. In such situations, coordination of the location of lines is still important but is directed toward securing conditions which will facilitate inductive coordination (such as keeping the separation uniform, avoiding frequent crossovers, etc.) rather than toward mere avoidance of exposures.

Uniformity of separation and avoidance of crossovers or other discontinuities are of great value because they permit telephone transpositions to be highly effective in reducing noise due to induction directly into metallic telephone circuits. Where additional inductive coordination measures are required, they are usually directed toward the control of power system influence and telephone circuit susceptiveness. The remainder of this article will be devoted to a brief discussion of these latter two subjects.

POWER SYSTEM INFLUENCE

The discussion under the heading of power system influence is entirely confined to rural power systems operating in the range of 11 to 13-kv and having single-phase extensions consisting of phase wire and neutral or two-phase wires. Some of the factors discussed are considerable different for other classes of circuits. Also, the discussion applies particularly to the influence of these circuits at roadway separation on either ground return or metallic open-wire rural telephone circuits.

The differences in influence between delta, uni-grounded neutral four-wire and multi-grounded neutral four-wire circuits and their single-phase extensions have been the subject of many recent discussions. Table No. 1 shows that for the 11 to 13-kv class of three-phase rural circuits and the 6.9 to 7.6-kv class of single-phase circuits, there is not much difference between uni- and multi-grounded neutral circuits, and that what difference there is, tends to be in favor of the multi-grounded neutral circuit.

These data, taken from a report of the Joint Subcommittee on Development and Research of the Edison Electric Institute and the Bell System[1], throw much light on this subject in that they show what happened in a number of cases when uni-grounded neutral 11-13-kv circuits and single-phase extensions thereof were converted to multi-grounded neutral circuits. Since all factors except the neutral grounding conditions remain unchanged, this comparision is the most valid practicable.

A summary of the test results showing how delta circuits compare with other types is given in Table 2. These data show that in the 11-13-kv class, the three-phase delta circuits tested had no advantage in general from the induction standpoint over uni- or multi-grounded neutral circuits.

The single-phase extension from a delta 7.2-kv circuit tested had almost as high a ratio of ground return I.T to phase I.T as the average of the extensions from 11-13-kv multi-grounded neutral circuits and half as high a ratio as the average of the extensions from 11-13-kv uni-grounded neutral circuits. (Incidentally, this table also shows the same general indication as to the relation between multi- and uni-grounded neutral circuits as the previous table; also, it shows that the range of values in any one class of three-phase circuit is much larger than the average range between different classes.)

It was not practicable in the tests to

[1] For all numbered references, see Bibliography at end of article.

Table No. 1. The comparisons illustrate the reactions in a number of cases when uni-grounded neutral 11-13-kv circuits and single-phase extensions thereof were converted to multi-grounded neutral circuits

Type of Circuit	Number of Comparisons	Number of Cases Where Ground Return I.T Product* Went Up When Circuit Was Converted from Uni-Grounded to Multi-Grounded Neutral	Number of Cases Where Ground Return I.T Product* Went Down When Circuit Was Converted from Uni-Grounded to Multi-Grounded Neutral
Three-phase 11 to 13-kv circuits fed from delta-Y transformer banks	7	3	4
Three-phase 11 to 13-kv circuits fed from direct-connected generators	9	3	6
Single-phase 7.6-kv circuits metallically connected to three-phase, four-wire circuits	4	0	4
Single-phase 6.9 to 7.6-kv circuits fed through single-phase transformers	8	3	5
Total	28	9	19

* I.T. product means the magnitude of a current (as measured with an ammeter) times its T.I.F. (the significance of which is discussed later). It has been found that, for rural distribution circuits of the class discussed here, the ground return I.T. product usually controls the inductive influence, except for exposures near the outer ends of circuits. Similiar data are given in the report and in an A.I.E.E. paper[2] based on this report, with regard to voltage induction but they are not reproduced here. The comparison for voltages shows no great difference for the two classes of circuits.

get comparisons on the same circuit operated delta and then with uni- and multi-grounded neutral; but by using the ratio of ground return I.T to phase I.T, the limitations involved in making comparisons between different circuits are minimized.

(From a practical standpoint, there is no reason why the phase I.T should be different for delta than for grounded neutral circuits if both circuits are the same otherwise—that is, have the same voltage, layout, wave shape, etc.—so that this ratio is a reasonable measure of the relative ground return I.T for delta and grounded neutral operation.)

The remaining class of circuit is the single-phase isolated (non-grounded) circuit. As long as the wires of such a circuit are kept free from grounds, accidental or otherwise, its influence is relatively low. However, since this circuit has certain serious disadvantages from safety as well as power operating standpoints, it has not been widely used.

Now we come to the factors which, from a practical coordination standpoint, are of the greatest importance in connection with power circuit influence. They are:

(1) Wave shape (i.e., the magnitudes and frequencies of the harmonics).
(2) Balance of the three-phase portions of the power circuit.

In order to appreciate the importance of these factors it is necessary to deal with them in terms of the *harmonics* in the power system voltages and currents; that is, the voltages and currents having frequencies which are multiples of the fundamental. Let us first see why, in any power circuit, it is the harmonics which are important from the noise frequency induction standpoint.

Through years of study and experiments the relative interfering effects of currents and voltages of different frequencies have been derived. Fig. 1 shows these relative effects for a number of the commonly-encountered frequencies (the reasons why the different frequencies have different effects and the methods used in evaluating these effects, are amply covered in existing literature[3, 4, 5] and need not be discussed here).

It will be noted that the range of influence effects of different frequencies is very large—to take the extreme, the influence of one ampere of 1020-cycle current is nearly 12,000 times as much as one ampere of 60-cycle current—so that, even though the harmonic currents and voltages on a power system are usually relatively small in comparison to the fundamental, their effect on influence is controlling. The order of magnitude of this control can be visualized by a simple illustration:

As a general measure of the influence of a voltage or a current, the product of "TIF" (Telephone Influence Factor) times the voltage or current is frequently used and is referred to as the Kv.T or I.T product. This factor is the square root of the sum of the squares of the products of the magnitude of each harmonic present in the *particular voltage or current* under consideration and the appropriate weighting factor taken from the curve of Fig. 1.

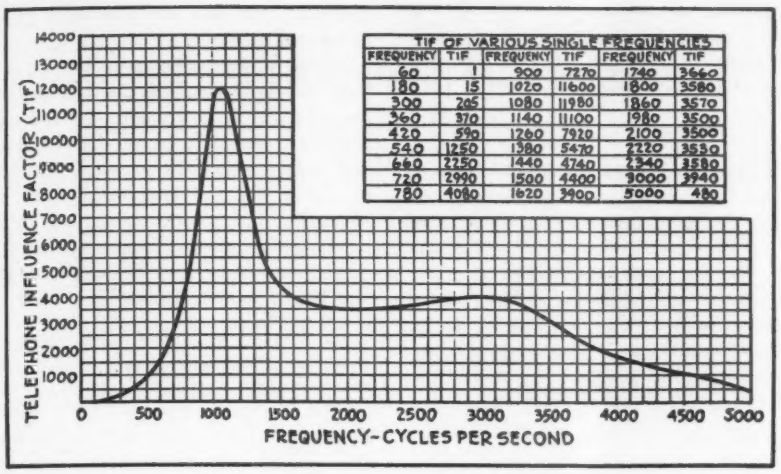
To obtain the TIF alone, this value is divided by the r.m.s. voltage or current as measured by an ordinary voltmeter or ammeter. A TIF of 20 for a voltage or current is not at all unusual; but it means that the influence of that voltage or current is *20 times as great* as the influence of a pure 60-cycle voltage or current of the same magnitude would be. Instruments containing weighting networks are available for measuring these quantities directly.

For rural power circuits of the 11 to 13-kv class, it is particularly important in considering inductive influence to think in terms of harmonics; not only because the harmonics are controlling in the influence but because the harmonics may arise at different places than the fundamental, follow different paths and be controlled by different factors.

Perhaps one of the most striking illustrations of this is in connection with a uni-grounded neutral or delta circuit. On a uni-grounded neutral or delta circuit, there is, of course, practically no 60-cycle current in the earth, but a relatively large proportion of the harmonic current may be in the earth—and it is

Table No. 2. Summary of tests which shows how three-phase delta circuits compare with other types of circuits

Type of Circuit	Number of Cases Tested	Ratio of Ground Return I.T to Phase I.T		
		Average	Minimum	Maximum
Three-phase three-wire 11-kv delta	4	.55	.16	.80
Three-phase, four-wire 11-13-kv multi-grounded neutral fed from delta Y transformers	12	.36	.10	.81
Three-phase, four-wire 11-13-kv uni-grounded neutral fed from delta Y transformers	7	.42	.16	.92
Single-phase extension, metallically connected to 7.2-kv delta circuit	1	.41	..	..
Single-phase extension from 11-13-kv multi-grounded neutral system	4	.62	.58	.64
Single-phase extension from 11-13-kv uni-grounded neutral system	4	.82	.78	.86



TIF OF VARIOUS SINGLE FREQUENCIES

FREQUENCY	TIF	FREQUENCY	TIF	FREQUENCY	TIF
60	1	900	7270	1740	3660
180	15	1020	11600	1800	3580
300	205	1080	11980	1860	3570
360	370	1140	11100	1980	3500
420	590	1260	7920	2100	3500
540	1250	1380	5470	2220	3530
660	2250	1440	4740	2340	3580
720	2990	1500	4400	3000	3940
780	4080	1620	3900	5000	480

Fig. 1. Frequency weighting characteristics for TIF measurements

the earth return harmonic current (ground return I.T product) which is usually the controlling factor in inductive influence, as pointed out previously.

In fact, the amount of harmonic earth return current may be—and frequently is—greater for delta or uni-grounded neutral circuits than for multi-grounded neutral circuits even though the 60-cycle earth return current is much smaller. (For those who would like to inquire further into the technical reasons for this, the brief discussion given in the appendix may be of interest.)

Now, thinking in terms of harmonics, it is evident that one of the important factors in the influence of a rural power circuit (regardless of whether the neutral is uni-grounded, multi-grounded or not grounded at all) is the wave shape of the voltages impressed on the circuit (i.e., the *frequencies* and *magnitudes* of the harmonics in them), since the harmonic voltages acting on the capacitances and impedances involved determine the ground return I.T, as well as the influence of the voltages themselves.

The other important factor just mentioned, is the *balance* of the three-phase system. Thinking still in terms of harmonics, it is usually more important on 11 to 13-kv lines to secure the best practicable balance among the capacitances to earth of the three-phase wires than to secure good balance among the loads on the three phases. The balance of these capacitances is controlled very largely by the single-phase extensions connected to the three phases.

If the number and lengths of the extensions are nearly equal for the three phases, and are distributed reasonably uniformly along the three-phase wires, the ground return I.T in, and hence the influence of, the three-phase circuit will be much lower (for given wave shape conditions) than if there is a large difference in the lengths and locations of the extensions.

The effects of the two factors just mentioned—wave shape and circuit layout—are much more important and show much greater variations between different circuits than the effects of the neutral grounding arrangements. It is not outside of the range of possibility that variations in influence of as much as 100 to 1 may occur between different circuits due to variations in these factors (which it will be observed later, is the same general order of magnitude as the difference in susceptiveness between metallic and ground return telephone circuits).

So far, little has been said about the effects of loads and load transformers. This is because they are not as important on 11 to 13-kv rural lines as the other factors discussed—with one exception. Occasionally, some unusual loads (such as a large motor with bad wave shape) may generate considerable harmonics which may give rise to an inductive coordination problem similar to that which may be caused by harmonics in the impressed voltage.

As to the effects of load transformers —on 11 to 13-kv circuits, with present standard transformer designs and with good voltage regulation, the magnitude of one of the higher harmonics in the impressed voltage is usually much more important than all of the transformers on the circuit put together.

One other point may be worth mentioning: It was pointed out previously that the influence of rural power lines is controlled by the ground return harmonic currents or occasionally by the harmonic residual voltages. Power circuit transpositions have no effect on the induction from ground return or residual components so that they are usually not worth while in rural power distribution circuits.

TELEPHONE CIRCUIT SUSCEPTIVENESS

There are two general types of rural telephone circuits which have been used quite extensively—the "ground return" and the "metallic." The difference in susceptiveness between these two classes is quite large—the ratios found by the Joint Subcommittee on Development and Research being in the order of 100 to 1.

Why there is inherently a large difference can be readily shown. The voltage *directly* induced into a metallic telephone circuit is only the difference between the voltages induced into the two wires of the circuit due to the fact that they are at different distances from the power line. For a ground return circuit, however, the induction into the wire is impressed directly in the talking circuit. An example may clarify this:

Consider one wire of a telephone circuit at a separation of 50 feet from a power line. The induced voltage per 1000 feet of exposure per ampere of earth return, 1140-cycle current on the power line, is about .87 volt.[6] For a wire 51 feet from the power line (the other side of the metallic open-wire pair) the induced voltage per 1000 feet of exposure per ampere of earth return 1140-cycle current is about .863 volt.

For a ground return circuit the induced voltage in the talking path at this frequency would be .87 volt (or .863 volt, depending on which wire is used), whereas for the metallic circuit made up of those two wires the induced voltage in the talking circuit would be only the difference between .87 and .863, or .007 volt.

In this example the ratio between the induced voltages for the two classes of circuits is about 120 to 1. The voltage in the metallic circuit is fequently referred to as the "direct metallic circuit induction."

In practice the voltage at harmonic frequencies in the metallic circuit may be considerably lower or higher than this inherent difference indicates. If the circuit is suitably transposed, the direct metallic circuit induction may be greatly reduced. To illustrate this let us use the example just discussed:

Suppose that, in the middle of the

1000-foot exposure considered in this example, the positions of the two telephone wires were interchanged; then the first wire would have a voltage along it of $\frac{.870}{2} + \frac{.863}{2}$ or .867 volt. The second wire would have a voltage along it of $\frac{.863}{2} + \frac{.870}{2}$ or, again, .867 volt.

There would, therefore, be not voltage tending to cause noise in the metallic circuit. Of course, in practice this degree of perfection cannot be secured; but the direct metallic circuit induction can frequently be reduced by a large amount by the use of suitable transpositions, particularly if the relative locations of the lines have been coordinated.

In an actual telephone line the transpositions are, of course, usually laid out and installed in accordance with regular patterns which minimize crosstalk between different telephone circuits as well as induction from power circuits.

The actual voltage acting in the metallic circuit may be higher than the inherent difference would indicate if the circuit is not well balanced. Unbalances may be of any of a large number of types, but the more common fall into the following classes:

1. Series resistance differences between the two wires of the circuit, usually due to resistance in the joints in the line wires.
2. Leakage differences between the two wires of the circuit, usually due to foliage growing into the line, missing insulators, wires against poles, dirt in protectors, etc.
3. Differences in the impedances to ground of the two wires at telephone stations, usually due to unbalanced connections of ringers of the lower impedance type to ground at the stations.
4. Differences in the impedances between the line wires to a ground connection in the line circuits or cord circuits in central offices.

The reason that unbalances can cause noise in the metallic talking circuit can be explained rather simply. Assume that we have a metallic telephone circuit in a relatively severe inductive exposure so that a substantial voltage exists on or along the wires of the circuit. Assume further that the exposure is perfectly uniform and the telephone circuit is perfectly transposed so that the direct metallic circuit induction is unimportant.

All telephone circuits have sufficient admittance to ground so that some harmonic current due to induction can flow in the wires. Now suppose that at some point in the circuit there exists a joint in one of the line wires having appreciable resistance.

The harmonic current in that wire flowing through this resistance will cause a harmonic voltage drop which is not matched by a similar voltage drop in the other wire and which, consequently, can

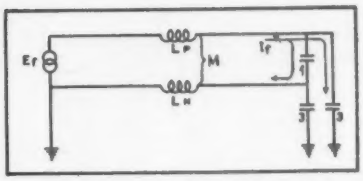


Fig. 2. Paths of harmonic charging current on short, uni-grounded single-phase line

drive current around the metallic circuit. This current, flowing through the receivers at the ends of the circuit, may be heard as noise.

Likewise, if there is more leakage on one wire of the circuit than the other, or if there is a difference in the impedances of the two wires to ground from any cause, the harmonic voltages between the wires and ground will drive more current through the wire with the lower impedance to ground and the greater voltage drop in this wire will tend to drive current around the metallic circuit.

It can readily be seen that a metallic circuit can be quiet in the presence of a strong inducing field only if it is adequately transposed and well balanced. Perfection, of course, cannot be secured and, consequently, while the metallic circuit is much less susceptive than the ground return circuit it is by no means immune to induction.

Conversely, it may be said that while the ground return circuit is much more susceptive than the metallic circuit, it can be operated under certain limited exposure conditions. It is fair to state, however, that the advantages from the induction standpoint of the metallic circuit are very great; not only because of the inherent improvement in susceptiveness but also because it lends itself more readily to the application of coordinative measures.

This article makes no attempt to discuss the wide range of coordinative measures available for application to the power and telephone systems; much less does it attempt to tell what measures would be best for any particular situation. An array of such measures is available and new ones are constantly being developed.

There is, however, no panacea; and long experience has demonstrated that the only way to secure adequate and economical cordination is for the telephone and power engineers to work together to obtain the best engineering solution of each problem as it arises. If they pay attention to the power system wave shape and balance and the telephone system balance and transpostions, the way is not too hard.

APPENDIX

This appendix discusses very briefly some of the underlying factors affecting the ground return harmonic currents on 11-13-kv rural power circuits and single phase extensions thereof.

The starting point in this analysis is the capacitance to earth of the wires of the circuit. (For 60 cycles these capacitances can usually be neglected.) Consider Fig. 2, which, for simplicity, shows the capacitances involved in a short single-phase extension from a uni-grounded neutral circuit.

The numbers opposite the capacitances denote their approximate *relative* magnitudes. (Neglect the inductances L_p, L_n and M for the time being.) It can be seen that for a harmonic voltage E_f impressed at the source, a harmonic current I_f will flow in the phase wire and that about three-quarters of this current will go to ground and become ground return.

Fig. 3-A shows the same circuit as Fig. 2, but now it is multi-grounded. All that multi-grounding does in this case is to short-circuit the capacitance between the neutral and earth, thus permitting the division of current between the neutral and earth to be controlled by the *self and mutual impedances* (L_p, L_n and M) rather than by the relative capacitances (see Fig. 3-B).

The self and mutual impedances are such in the usual case that about 50 to 60 per cent of the charging current is earth return rather than the 75 per cent which occurred in the uni-grounded

(*Continued on page* 423)

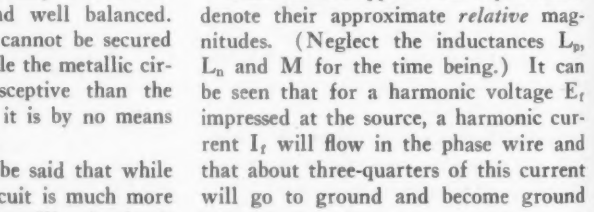


Fig. 3. Paths of harmonic charging current on short, multi-grounded single-phase line

Bibliographic Potentialities of Electric Utilities

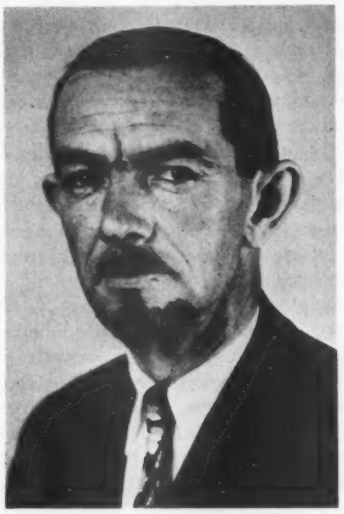
By Charles L. Palmer
San Joaquin Power Division, Pacific Gas & Electric Company

THE problem of utility public relations lies not alone in those measures designed to meet the exigencies of the moment but also in the long time development of a public comprehension of the place in the national and local life occupied by the utilities.

There are, of course, many ways of developing such a comprehension and these, in the main, have been discussed and written about from the time the first utility public relations problem arose. Yet there is one phase of public contact which is valuable in the dissemination of factual information about utilities, which should aid in the creation of favorable understanding of the utilities, particularly electric utilities, and which has been entirely overlooked. This phase is the development of a popular literature, not alone about the utilities themselves as such, but also about the men who created them and who operate them.

It is extremely doubtful if there is an electric utility in the country today that has not built up some traditions connected with its pioneers. Certainly, those engineers, financiers, administrators and operating men of fifty or more years ago, feeling their way along in a new and untried field and building their communities as they themselves progressed, encountered obstacles and developed solutions to their problems as they went along that not only would make good reading today but would tend to throw the light of public understanding on the reasons why any particular utility has developed as it has.

There is a lack of popular literature about the electric utilities and the men who made them. Some information can be found in the reference rooms of the better libraries, but there is neither comprehensive nor specific, especially specific, information on utilities or utility men written for public consumption available in volumes of general circulation. The New York Public Library, with all its vast resources for bibliographic research, in response to a request, listed only one popular history of the electric industry in the United States, The Story of Electricity, by



MR. PALMER

Thomas Commerford Martin and Stephen Coles, and that published in 1919. Further, that one volume generally is not available in the average public library, but is to be had only by recourse to research libraries. The New York Public Library provides a bibliography of electrical inventors and physicists, but most of the references are thumb-nail biographical sketches and there is not one popular biography of any electric utility founder or subsequent operator listed.

The Smithsonian Division of the Library of Congress submits a similar list, but F. E. Brasch, Chief of the Division, says:

"Biographies of those who have aided in the operation and financing of electrical utilities are inexhaustible, and would require too much time to prepare. Owing to the length and variety of such a list, we would recommend that the inquirer consult Moody's Manual of Industry for a list of Directors and Officers of electrical concerns, many biographies of whom may be found in Who's Who."

Mr. Brasch is correct. The brief facts of birth and position of many electric utility leaders may be found in reference volumes, such as Who's Who, but this only serves to emphasize the lack of popular writings giving details of their lives and times.

Yet even the biographical information available for research is not complete. The National Cyclopedia of Biography, as indicated by White's Conspectus for 1935, carries brief biographical sketches of but four of the fifteen presidents of the American Institute of Electrical Engineers between the years 1921 to 1935 inclusive. These four are Frank B. Jewett, Michael Pupin, Bancroft Gherardi and William S. Lee. Now, the National Cyclopedia of Biography is primarily a reference work and certainly is not a popular volume, nor are the various presidents of the American Institute of Electrical Engineers essentially electric utility officials.

A similar dearth of popular electric utility information is to be found in other libraries than the New York Public Library or the Library of Congress. The development of electric utilities and electric service has been as outstanding in the State of California as in any other state in the nation. The very fine and very beautiful bibliography of Californiana prepared by Robert Emmett Cowan and Robert Graniss Cowan, and printed by John Henry Nash, lists no single volume dealing with the development of electricity in that state, with the history of any California utilities, either for popular or research purposes, nor with the lives of any of the men who pioneered and developed the electric industry in that state. The California State Library is without such volumes and, by inference, through failure to answer inquiries, so is the Bancroft Library of the University of California. It is entirely reasonable to suppose that similar conditions obtain in similar libraries in other states and other localities.

What, then, is the nature of the literature available about the electric industry and the men who developed their electric utilities? Hungerford, in his volume, The Story of the Utilities, devotes one chapter to the treatment of electric utilities. The rest of the book treats of other utilities, particularly railroads, on which Hungerford is an

authority. This volume is written in a popular vein and is one of the few volumes of its kind giving a popular, if brief, up-to-date story of the electric utilities. A reference volume, Men and Mergers, by Dr. Hoxie, discusses the financing of electric utilities, but this is not listed in most library catalogs.

There have been, of course, numerous magazine articles dealing with the electric utilities, both for and against, but in the main these have discussed social aspects of electric power. To get even this information from magazines very difficult research work is necessary and it is sometimes essential to know the name of the author or the title of an article before it can be located. The utility industry does have a literary publication in the *Public Utilities Fortnightly*, but this is written for executives, accountants and engineers within the industry and by no means can be regarded as filling the need for popular literature on the industry.

In a typical library serving an urban and rural population of approximately 150,000, there are some three hundred volumes dealing directly or indirectly with electrical subjects. These are primarily textbooks, research material or discussions for or against public ownership of electric utilities. There are, in the list, exactly two histories of electricity, A Century of Electricity, by Mendenhall, published in 1887, and The Story of Electricity, by John Munro, published in 1902, and neither of these deals with the electric utility field of today.

As has been said, there are no popular biographies listed of the men who built even the major utilities of the country. There is one biography, in this instance the Autobiography of John Hays Hammond, mining engineer, in which he briefly touches upon his part in the electrical development of the West. There are biographies of Thomas A. Edison, Charles Proteus Steinmetz, Benjamin Garver Lamme, Michael Pupin, Elihu Thomson and other electrical engineers, inventors and physicists, but they were not primarily electric utility men.

Most important, there is a proportionately heavy number of volumes by Stuart Chase, Gruening and others, advocating political control and operation of electric resources. There is a report of the collective operation of electric resources in the Union of Socialist Soviet Republics.

Finally, there is one novel, The Rules of the Game, by Stewart Edward White, in which the author sandwiches an attack on electric utility methods into a book on the lumber industry.

This typical library is probably a little better than average in the number of volumes available. In the reference room and not available for circulation are government reports, utility commission reports and state reports on water and power resources; highly statistical and by no means to be considered entertaining, even though educational, reading. There are the usual reference books and volumes treating of individual inventors and physicists. There is a pamphlet, dated 1923, giving the resources of the Pacific Gas and Electric Company. There is a small volume, published that same year, giving the principles and ideas of Henry L. Doherty and published for the guidance of men in the Doherty organization. There are volumes on electric currents, electric discharges, electrical engineering, electric lighting, electric motors, electric meters, electric occupations, electric resistance, electric safety orders and on the social aspects of electric power. The list is impressively educational and highly technical but a study of publication dates would indicate that the major part of the selection, with the exception of the political volumes, is sadly out of date.

These are the volumes that the general public finds when it goes to this library for information about the electric industry; about electric utilities and about the men who built them.

There is only one conclusion that can be derived from an inspection of the electrical volumes in the average public library, viz.: the electric industry as a whole is inadequately represented, even in reference volumes, and the main representation that is given to electric utilities is in the form of volumes attacking those utilities from the standpoint of political or economic theories. And, repeating for emphasis, there is no popular literature of any sort dealing with the electric utilities or the men who built and operate them.

On the other hand, there are historical and biographical volumes dealing with the railroad industry, the steel industry, the automotive industry, the banking industry, to name a few, and with the men responsible for the development of those industries. Yet these industries and their leaders have accomplished no more for the advancement of social and economic standards; have had no more romantic experiences or solved no more difficult problems than have the men who conceived and nurtured the electric utilities of the country.

In a few instances, biographies of utility founders and executives have been written and published privately as memorials by their own organizations. Two such volumes come to mind. One treats of the life of L. L. Nunn, founder of the Telluride Power Company, most of which later became the Utah Light and Power Company, and the other is about the life of William G. Kerckhoff, of the Pacific Light and Power Company, now part of the Southern California Edison Company, Ltd. system, and also once president of the San Joaquin Light and Power Corporation, now part of the Pacific Gas and Electric Company system. But volumes such as these are few and far between and, as testimonials, cannot be expected to maintain the full impartiality essential to complete acceptance as reference biographies, although they are authoritative as far as they go.

If biographies of men in the electric industry, and if histories of the electric utilities are to be written, an impartial attitude must be maintained. The records will speak for themselves. General credence in such attempts at public literature will be lost if argumentative explanations of debatable points are presented. And if general credence is lost the public relations value of such literature will be lost. To be of greatest value in building public relations, sympathetic yet factual presentations of controversial questions are necessary in writing the lives of industry leaders. In such biographies it is always permissible to draw conclusions but never solely on the basis that the end justifies the means, nor without presenting the facts and conditions of both sides of any controversial question at the time that question was decided—not in the light of later knowledge. The public relations value of public opinion reached voluntarily on facts impartially presented is far more lasting than opinion induced through argument.

To this end, it is essential that electric utilities and the electric industry in general offer every facility to biographers and historians seeking records and information. The records will speak for themselves. Yet it is entirely possible that the present lack of popular literature about utilities, utility founders and executives is partially due to the

difficulty encountered in gaining access to source material. It cannot be due to any assumption that the men of the industry have not been worth writing about.

The fault does not lie wholly with the utilities, however. Here is a whole field for biographical and historical research that has never been touched by the writing fraternity and on that group lies some of the blame. From the standpoint of the writer and from the standpoint of the publisher such material is unquestionably marketable if it is presented in popular and comprehensive form and maintains a reasonable standard of literary excellence, but it cannot be argumentative, didactic or technical. Sales rights and royalties should prove compensatory for the research required.

It is not even necessary to go outside the electric utility industry to find men and women capable of unearthing and writing the information essential to such works as are under discussion. There are many trained writers in the industry; they are capable and, in most utilities, have served their localities long enough to feel the traditions of the atmosphere and circumstances surrounding their subjects. These men and women in the industry will have more ready access to dusty utility records and greater facility in interpreting the technicalities of electrical language into terms capable of lay comprehension. Finally, these men and women, while maintaining an impartial attitude in the selection and discussion of material, will not have a bias of current too prevalent social or economic theories and can make sensitive presentations of material available.

Most important of all is the fact that the electric utility industry has had a life of approximately three score years. Most of the men concerned with the founding of any utility are no longer living. Those that are have but a few short years, at most, in which to offer for record their first hand recollections of circumstances and events. The historical value of the memories of the pioneers still living is a heritage of the utility industry that soon will be lost unless immediate efforts are made to preserve it. The importance of this cannot be overemphasized. Bare fact, without the enlivening chiaroscuro of anecdote and memory, is a dull and uninteresting picture, indeed, and early records soon will lose the supporting charm of contemporary memoirs unless steps are taken to preserve the latter at once.

Now, while it cannot be argued that the development of a popular and factual literature about the electric utility industry and its outstanding figures will have any immediate beneficial effect upon the current public relations problems of the electric utilities, it can be stated that such a literature will have an indirect but helpful effect on them in the future. The development of such a literature as is advocated here eventually, by reason of presenting accurate and authentic historical information, would bring about a greater public understanding of the circumstances surrounding the development of specific utilities by men who have been an influence in their communities, and would offset much of the misinformation currently circulated both about the utilities and their executives. A truthful literature about the utilities would be a beneficial addition to reference libraries of schools and colleges as well as of public libraries.

On the West Coast, for instance, a greater knowledge, brought about by the presentation of factual literature, of the lives, the aims and the methods of such men as John Martin, Eugene DeSabla and John A. Britton of the Pacific Gas and Electric Company; of John B. Miller and R. H. Ballard of the Southern California Edison Company, Ltd.; of Albert Graves Wishon of the San Joaquin Light and Power Corporation, and many others, would permit a greater public understanding of the reasons why the electric utilities of the West have been able to develop their services to their present high standards and might well add to local pride in those utilities. The life of Henry L. Doherty, who has been mentioned, would be an integral part of any literature on the utility industry. The political and administrative genius of Wendell L. Willkie and the financial acumen of Harrison Williams and Sydney Z. Mitchell are vital parts of utility history that should be recorded for posterity. Further, an impartial analysis of the life and works of Samuel Insull probably would develop that the benefits be conferred by his activities are more lasting than any damage he may have inflicted. These are just a few of the possibilities the field offers.

To summarize, an examination of catalogs of even the finest libraries reveals the lack of any popular literature, biographical or historical, concerned with the electric utility industry and its executives, though other industries, no more important, are well represented. The libraries would list such literature if it had been published. A popular literature should be developed to fill that need. Such works should be factual and impartial rather than argumentative, didactic or technical. There are men and women in the electric utility industry trained to write and capable of producing such volumes. They should be given free access to utility records and should draw at once upon the recollections of those electric pioneers yet alive who can throw the light of first hand information on early day circumstances. Such biographies and histories, if properly compiled, would prove marketable and would find their way into public acceptance through the medium of public libraries and the reference libraries of schools and colleges. Authentic information on specific utilities, made available in this way, would have an indirect but lasting influence upon public understanding of the electric utilities and their problems, and this, in turn, would have a beneficial effect upon the public relations problems of the electric utilities.

Serious and immediate consideration of this proposal is urged upon the several electric utilities of the nation. The utilities have nothing to fear from the truth.

The field is open and the material is still available.

An Effective Load Building Device

(*Continued from page* 389)

such a manner that brush contactors or photo-electric cells could be made to operate a "counter" for each station, indicating at all times, on the "counter," the economic load for the station. By proper circuit design another "counter" can be made to indicate the total demand or output of all stations. If desired, the economic load thus indicated for each station can be transmitted directly to the station and there give remote indication or even remote control of the load. In building one of these devices, the value and cost of each feature must be weighed. The device, as shown in Fig. 2, is one that has given excellent results in actual use over an extended period of time. Its design can be clearly seen in the photograph, and it probably represents the simplest and cheapest method of construction of a device offering such flexibility in use.

Studies on Conductor Vibration

By Leonard C. Peskin

Engineer in Charge, Transmission Engineering Department, American Steel & Wire Corp.

A paper presented before a meeting of the Transmission and Distribution Committee, E.E.I., Chicago, May 4

WITHIN recent years the problem of conductor vibration has received more than passing attention from those associated with the field of electrical power transmission. This fact is amply attested by the numerous articles which have appeared on this subject in transactions of the American Institute of Electrical Engineers, and other publications. Discussion, however, has been concerned mainly with the causes and nature of the vibration phenomenon as it exists in a transmission line. Very little has been said about the metallurgical relation of conductor vibration to the fatigue of metals, for only within recent years has equipment been made available upon which this metallurgical-mechanical phase of the problem can be studied.

Increased activity in the rural electrification programs of both the government and the utilities has made necessary an intensification of these studies. This is essentially due to the fact that the economics of rural distribution line construction necessitates the development of light-weight, high-strength conductors which can be strung to high mechanical tensions, to permit unusually long spans between poles. While such a trend in design is progressive, and represents a most efficient use of conductor material, it nevertheless has, for reasons which will be shown later, aggravated the vibration fatigue problem to the extent that it is perhaps the most important single problem with which one has to deal in the construction of such rural lines.

It is the purpose of this paper to review, briefly, the nature of conductor vibration phenomenon with which we are confronted to show its relation to the fatigue properties of conductor metals, and to describe what is being done in the field and laboratory to overcome in a practical fashion the damaging effects of this undesired motion.

Characteristics of Conductor Vibration

A discussion of conductor vibration involves two distinct types of motion. The first is a low-frequency, high-amplitude displacement of the conductor, which is commonly known as the "dancing" or "galloping" conductor. This is a phenomenon which results from a special set of conditions, namely, the formation of sleet on the line, coupled with a lateral wind. When the sleet forms in such a way that the normally round cross-section of the conductor is changed into one resembling an air foil, aerodynamic forces are derived from the wind, resulting in a lifting or depressing motion of the conductor at a very low frequency, and through an extremely large amplitude. This situation is at once overcome by removal of the sleet, and while the motion can cause considerable annoyance and damage, the damage is usually of an electrical nature, as a result of short circuits, or of a mechanical nature, as a result of excessive distortion of pole assemblies. Conductor fatigue does not generally occur from this type of motion, consequently further comments with respect to the "dancing" conductor will be omitted in what follows.

The second type of conductor vibration, and the one with which we will be concerned, is the high-frequency motion which is so commonly observed in rural lines. Depending on certain conditions, this motion may take place at frequencies which vary from ten cycles per second to over two-hundred per second. Corresponding amplitudes, considered as the over-all conductor swing vary from approximately 0.2 in. to less than 0.01 in. This phenomenon takes place under conditions which might be considered ideal from all other points of view; in fact, it is the gentle, but steady wind which causes the motion, and the conductor itself need not be covered with ice.

What the nature of the forces are which give rise to this high frequency motion may be understood from Figure 1. This sketch shows the conductor being subjected to a lateral wind, which is laminar in its flow, and normally exists in winds whose velocities vary from two miles per hour up to ten miles per hour. It is a known fact that a periodic formation of eddies will occur on the lee side of a conductor subjected to such an air stream. The theory concerning the formation of these vortices has been investigated by von Karman[2] and others.

In a qualitative fashion the phenomenon may be understood by considering, as may be assumed in Fig. 1, that the boundary friction between the conductor and the air stream is greater, in a given instance, on the bottom side of the conductor as compared to the condition existing at the top. The normal velocity of the wind stream will be somewhat diminished at this point, and associated with this lower velocity will be an increase in pressure, relative to points in the air stream at the upper portion of the conductor. There will be a resulting flow of air particles behind the conductor, forming a vortex, as shown by the sketch. This condition of turbulence, however, will impede the flow of air over the top of the conductor, and there will be a resulting drop in velocity at this point with a corresponding increase in pressure relative to the bottom. The vortex formation will then occur behind the conductor, in a manner as if the air stream were flowing from the upper side of the surface. This condition will upset the boundary situation at the bottom, and the next vortex will form from below.

In this rather qualitatively explained fashion, there will be an alternate formation of eddies, first from the bottom of

Fig. 1—Air stream about conductor

[2] "Flussigheits und Luftwiderstand," von Karman and Ruback, Physik Zeitschnift, Vol. 13, 1912, p. 49.

the conductor and then from the top. Associated with each eddy is a resultant pressure, first on the bottom of the conductor and then on the top of the conductor. As a result the conductor finds itself subjected to periodic impulses which occur at the rate of formation of the vortices. Studies by Relf and Ower[3] show that within the range of wind velocities, during which the air stream is laminar, the frequency at which these eddies form, or the corresponding pressure impulse frequency, is proportional to the velocity of the wind and inversely proportional to the effective diameter of the conductor. The frequency formula of Relf and Ower has been checked in numerous observations made by the Aluminum Company and others, and it is at once obvious that the smaller the conductor the higher the frequency at which the exciting forces impinge upon the suspended line.

One must now appreciate the fact that the conductor suspended in mid-air represents an elastic system very much the same as a stretched string, and as a consequence possesses a great many modes of vibration, these being commonly referred to as "critical frequencies." In the case of small conductors such as are used for rural distribution work, these critical frequencies lie so close to one another—particularly at the high values at which they occur in practice—that the periodicity of the alternating pressure arising from the conditions of turbulence behind the conductor will very nearly coincide, if not exactly coincide, with some one of the critical frequencies with which the suspended conductor can vibrate. A condition of resonance is set up, and the distribution line will vibrate in relatively short loop lengths, depending on the frequencies then being derived from the wind at any given time. The amplitude through which the conductor moves will depend upon its elastic properties as well as the amount of damping inherent in the conductor system. This last will include such boundary conditions, as ties, hardware, or other accessory devices used in conjunction with the suspended conductor.

As a result of this vibratory motion, there are superimposed upon the static stringing tensions existing in the conductor, alternating stresses of two characters. The first is a bending stress, due to the apparently sinusoidal distortion of the vibrating conductor. The second stress is one due to the stretching of the conductor as it goes into its sinusoidal shape, in each of its loops. In addition, because of these stresses there is motion of the conductor relative to its points of support, and serious conditions involving abrasion of conductors and ties will inevitably follow.

[3] "The Singing of Circular and Stream-Line Wires," E. F. Relf and E. Ower, Aeronautical Research Committee, No. 285.

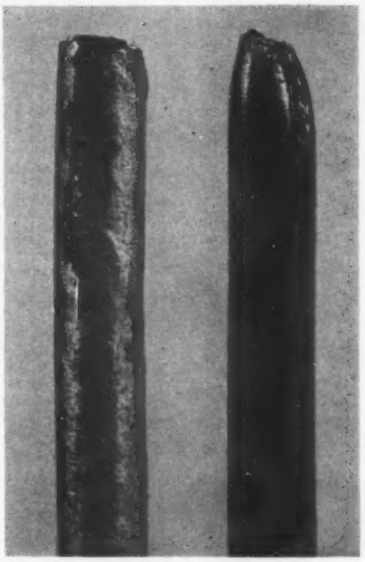


Fig. 2—Dynamic and static fractures of wire

Dynamic and Static Failures of Metals

To thoroughly understand the relationship of these alternating stresses to the failure of the conductor material, it is important to distinguish between a fatigue failure, or dynamic failure of the metal, and the static failure as commonly observed in ordinary tensile testing of wire, due to overloading the specimen in the field.

Fig. 2 shows two pieces of wire which have been ruptured in the laboratory; in one case by a statically applied load, and in the second by a dynamic or alternating stress. The static overload produces in the metal a characteristic necked-down fracture, resulting from an actual flow of the metal during the process of distortion, with subsequent rupture. Failures of this type are observed in conductors as a result of excessive loads being applied to the conductor, such as those resulting from falling trees, heavy ice loads, and even large displacements resulting from the phenomenon of the "galloping" or "dancing" conductor. Unless the fracture has been burned as a result of the passage of a heavy flow of current, such failures are easily recognized in the field.

The other wire shows the characteristic dynamic failure of metal. This is a rupture of the material, with no reduction in cross-section. It comes about through the formation of a microscopic crack, whose origin is at some point of maximum stress, a point that is always on the surface of the wire in the case of conductors and at a position, ordinarily, where abrasion or some other agent has brought about a weakening of the surface strength of the material. Under the influence of alternating stresses, this crack will propagate through the material, and normally will proceed to a point where sufficient area has been disrupted, so that what remains is insufficient to carry the existing stresses imposed upon the structure. The failure is then completed, much the same as a static overload, so that in actual field failures the conductor which has failed because of fatigue will show a fracture that is partially undistorted as a result of the initial stages of the crack propagation, and a portion of the cross-section necked-down because at that instant the area of metal left was insufficient to carry the catenary tensions. Here, again, failure of this type can be readily recognized with a little experience, unless, of course, a burn has completely distorted the original formation.

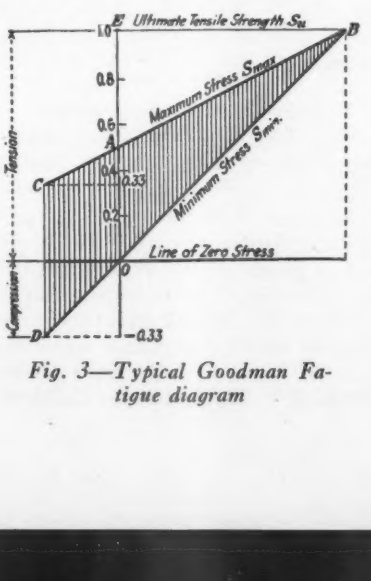


Fig. 3—Typical Goodman Fatigue diagram

Relation of Stress to Fatigue

Let us now consider what laboratory studies on the subject of fatigue have shown, and how these investigations are applicable to the problem of conductor vibration.

Fig. 3 is a Goodman diagram, which is a means of representing the characteristics of any metal with respect to its fatigue properties, when subjected to alternating stresses. Consider, for a moment, the extreme left-hand side of the diagram, which represents the situation in which a metal is subjected to alternating stresses in compression and tension, each of equal magnitude, so that the average

stress in the material is zero. It is found that under these conditions any material will submit, without danger of failure, to the widest stress range for an indefinite number of cycles or alternations of stress. It is an unfortunate circumstance that heretofore most fatigue studies in the laboratory have been based on experiments subjecting the material to conditions of this kind. One of the reasons is that it has been relatively easy to develop fatigue machines such as a rotating-beam machine, which submits the metal only to that kind of alternating stress which passes through an average of zero. Later research, with more advanced equipment, has shown that if the same material is subjected to a stress range which has an average value differing from zero, the range must be considerably reduced before the same metal will undergo an indefinite number of stress alternations. This reduction in stress range, with increased average stress, is so pronounced with most metals, that considerable care must be exercised by designers in developing structures subjected to this type of loading. This behavior of metals has a direct and important bearing on the life of a conductor, for obviously, as the economics of rural construction with respect to distribution lines has led to the development of high strength conductors, the stringing stresses thus represent the average stress about which the alternations due to vibration take place. Consequently, as may be concluded from the foregoing, the higher the stringing stress existing in the conductor, the smaller the stress range, or the smaller the amplitude of vibration permissible for indefinite life, without fatigue failure, while subjected to dynamic loads.

It is important to realize, at this moment, that the stringing stresses as limited by the design code are, of themselves, ordinarily insufficient to cause early fatigue of the metal. This is one of the reasons why fatigue failures of the conductors are rarely, if ever, found in the middle of the span away from any discontinuity such as is presented by a splice, connector or tie. Nevertheless, the principles outlined hold at any point in the conductor; therefore, it is important to understand that at such discontinuities as previously mentioned, the average stress which exists is not only that produced by the stringing tensions, but also, in addition, the stress due to concentration, resulting from sharp curvatures, as are imposed by some types of hardware and ties, and discontinuities resulting from certain massive accessories, which

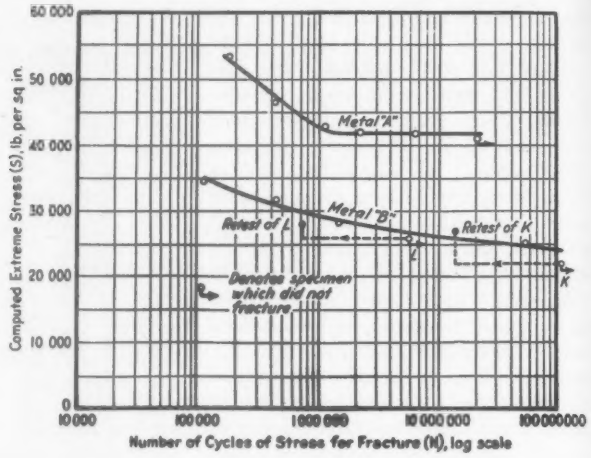


Fig. 4 — Endurance curves for ferrous and non-ferrous metals

again add considerably to the stresses normally arising from stringing conditions. Thus, at these points, the average stress in the conductor is considerably higher than what might be expected, and when one considers applied at these points the alternations of stress due to conductor vibrations, conditions of a very severe nature are met, resulting, frequently, in early fatigue failures.

While we have confined our attention to stress characteristics of the fatigue phenomenon, we must not forget that there is an important time element also involved. In other words, we have indiscriminately used the word "indefinite" with respect to the life of the material under alternating stresses. This extended life is highly desirable, naturally, and can be achieved with some metals, as will later be explained. From the point of view of laboratory studies, however, one considers "indefinite" in terms of millions of cycles of stress through which the material will pass without failure due to fatigue. Studies of this kind are shown in Fig. 4, which has plotted as its ordinate, the extreme value of the stress range to which the material has been subjected (in this case there was an average stress of zero). The abscissa shows the number of cycles of stress before failure took place.

Fatigue Characteristics of Metals

Most metals give one of two characteristic curves, as shown in the case of "Metal A" and "Metal B." Metal A is characteristic of the behavior of steel subjected to fatigue stresses. First of all, ferrous metals can withstand extremely high alternating stresses without danger of failure, as compared with those withstood by non-ferrous metals, whose behavior is indicated by the curve labeled "Metal B." This means that a material such as steel, or one which behaves like steel, will have a greater factor of safety when subjected to vibratory stresses, as exist in rural distribution lines.

What is of equal importance, however, is the shape of the curve. It is apparent that in the vicinity of 2,000,000 cycles of stress, the curve for Metal A has straightened out, and is approaching an asymptote. This asymptotic value of the stress is commonly known as the endurance limit of the material, and represents that stress to which the metal can be periodically subjected and still show no failure for an indefinite length of time. In American practice it is common to test ferrous metals until no failure is obtained for 10,000,000 cycles, at which time the endurance limit is definitely established. European practice has dropped this value down to about 2,000,000 cycles.

Metal B, however, which is typical of aluminum, copper, lead and other non-ferrous materials, with the exception of some interesting non-ferrous alloys such as Beryllium Copper, not only shows a lower range of endurance values, but it is questionable as to whether any final value actually exists. As the tests are extended, the curve continues to slope downward, apparently reaching no definite value. As a consequence, it appears that in cases of metals such as these, stress concentrations must be reduced to extremely small values before any assurance of prolonged life is possible. In fact, in European practice it is common to extend fatigue tests on metals such as these (as, for example, in the case of aluminum) to 200,000,000 cycles before design values are established. It is at once obvious, therefore, in the case of non-ferrous metals, that extra precautions are necessary to reduce stress concentrations arising from the use of improper acces-

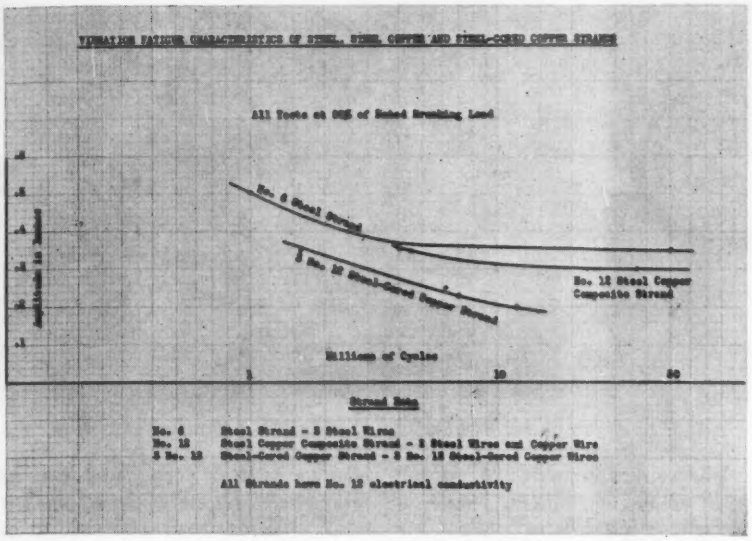

All Tests at 50% of Rated Breaking Load
No. 6 Steel Strand
No. 12 Steel Copper Composite Strand
Millions of Cycles
1
10
50
Strand Data
No. 6 Steel Strand - 3 Steel Wires
No. 12 Steel Copper Composite Strand - 2 Steel Wires and Copper Wire
3 No. 12 Steel-Cored Copper Strand - 2 No. 12 Steel-Cored Copper Wires
All Strands have No. 12 electrical conductivity

Fig. 5—Vibration fatigue tests on rural high strength conductors

sories in connection with conductors, and to minimize any abrasive conditions which always tend to reduce the normal fatigue resistance of the metal involved.

It is interesting to consider, for a moment, the length of time involved from a practical point of view, in reaching a critical number of stress alternations for a given set of conditions, as might exist in the field. As the stringing tensions have increased on conductors, the sizes have become correspondingly smaller, and the span lengths larger so that greater quantities of wind energy are picked up, the critical frequencies involved in the conductor vibration have become higher. These frequencies range between 100 and 200 cycles per second, and the fact that they are in the audio-frequency range may be readily appreciated when one realizes that this motion can be heard in the vicinity of the distribution line.

Naturally, with the higher frequencies involved, the length of time required in reaching a given number of millions of cycles becomes shorter. If this number of stress alternations is a limiting one for the stress that may be involved at some point of concentration, the length of life remaining in the conductor may become extremely small; unless, of course, conditions arise which mitigate against a fatigue failure.

The Behavior of Rural Conductors in Fatigue

Let us now apply the foregoing to an actual set of experiments in the laboratory, which demonstrate the true behavior of typical rural lines subjected to vibratory stresses. The results are shown in Fig. 5.

Tests have been made on three conductors, all having equal electrical properties, so far as conductivity is concerned. These tests have been made with the conductors stressed to 50 per cent of their rated breaking load, and at frequencies determined from actual measurements in the field. In each case the conductors were tied to Pin-type insulators in the manner recommended by the wire manufacturer. Failure was considered to have taken place when one or more wires of the three wires in each strand are broken. As may be expected, the all-steel strand showed a typical ferrous curve, and gave the highest endurance value when subjected to vibratory stresses, the corresponding amplitudes for which are given by the ordinate axis.

The characteristic behavior of a non-ferrous material is shown by the curve given for the No. 12 copper covered steel strand. This brings out an important fatigue property with respect to material which is bi-metallic in the sense that a core of one kind is surrounded by a surface material of another type. So far as fatigue is concerned, a failure of this kind will take place at that point in the material at which the stress exceeds the endurance limit of the metal. In vibrating conductors, this point is always at the surface, in the vicinity of some stress concentration or surface damage. In a bi-metallic material, as described, the surface is distinctly hard drawn copper and has the characteristically poor fatigue properties of copper. Consequently, the fatigue crack will start under conditions no different from those which would initiate a failure in a solid hard drawn copper wire. One might assume that the propagation of this crack would be seriously impeded by the presence of the steel center; however, at the surface of the steel core, conditions are no longer favorable for extended endurance life. Due to the crack in the surface material, the steel core is subjected to a notch of the sharpest type, one that is atomic in its dimensions. At the base of this notch, which is at the steel surface, more than ordinary stresses arise, and the endurance limit of the steel itself will be exceeded; consequently, as is shown by actual tests, the crack will propagate itself into the steel center with little interference, and the cross-section will soon be reduced to a point where it will fail because of static overloading. Let us consider the mechanical fatigue characteristics of another distribution of steel and copper, wherein the three-strand structure is composed of one copper wire and two steel wires or two copper and one steel wire. Those of you familiar with the distribution of stress in such a composite strand will recognize at once that due to the larger area and higher modulus the steel will carry by far the greater proportion of the total stringing load. As a result, one has, from a fatigue point of view, the proper distribution of stress in a strand involving both steel and copper. The maximum stresses are in the steel, and the stress which exists in the copper is reduced to a very low value. As may be anticipated, such a composite strand behaves, in the same set of tests, in a manner that falls somewhat in between the two materials previously discussed, but shows, eventually, the characteristics of the all-steel conductor. In other words, while the endurance values reached are not as high as the all-steel strand, the asymptotic characteristics are eventually approached, and the desirable fatigue characteristics of steel obtained.

Measurement of Vibrations in the Field

So much for the theoretical studies of the fatigue of metals, and their relation to conductor vibration problems. We shall now discuss, briefly, the methods of investigating and studying the problem, both in the field and in the laboratory. Figure 6 is an inertia pendulum type of device, which has been used in the past for recording the vibration of transmission lines. While it has proved of some value in connection with lines having large mass, it is of no use in the case of the very light rural lines. In field mea-

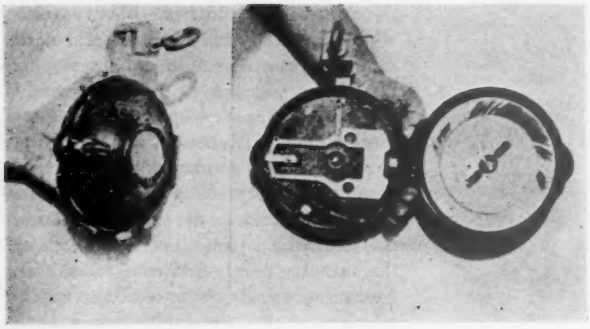


Fig. 6—Inertia pendulum vibration recorder

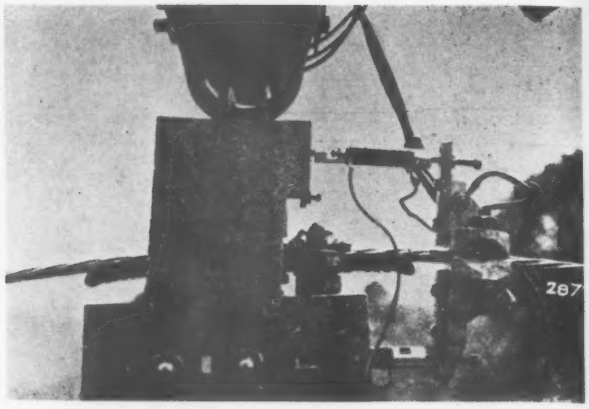


Fig. 7—Carbon pile vibration pickup

surements, one is immediately confronted with the problem of using instruments, the application of which to the line must not modify its elastic and dynamic characteristics. Such an instrument as shown in this picture is so massive that its application by hanging to the rural line, would immediately change the entire nature of the structure and its recordings would be of no value, since they would have little relation to the situation, as it actually exists.

Figure 7 is another type of device, which has been used for studying the dynamics of vibrating lines. Once more, the use of an instrument of this type is limited to structures wherein its own mass and stiffness characteristics would not modify those actually existing in the unencumbered line. Since the device shown in this picture contains considerable stiffness and mass, it is obvious that its use is again limited to the very heavy types of transmission lines, and that it could not be used on a light rural conductor.

Unfortunately, I am unable to show a picture of a device which is being used with great success in studying field conditions as they exist in the light rural types of lines. The results of these investigations have been made available to us, and have served as a field check on our laboratory studies. In brief, this apparatus consists of a series of spans which can be adjusted from 400 to 800 feet in length. It is located in open plains country where prevailing winds have been known to do damage to conductors. A tower has been built adjacent to the conductor near one of the points of support, and from this tower is hung the heavy magnet parts of a moving coil pickup. The moving coil itself, which weighs but a fraction of an ounce, is attached to the conductor so that it moves in the field of the suspended magnet. The voltage generated in the coil is picked up and amplified by a series of instruments which eventually produce a continuous 24-hour record of both the frequency and amplitude of the vibrations. Other instruments permit continuous readings of wind velocity, wind direction, and tension variations in the conductor itself.

Observations have been made on various types of conductors, and have revealed some extremely interesting and important facts. For one thing, the results have confirmed the range of frequencies to the expected on rural conductors, as indicated by theory, and have shown pronounced vibration frequencies on some conductors of over 200 cycles per second. The amplitudes measured have been found to be very small, but in many instances can actually be observed by eye.

Vibration Properties of 3-Wire Strand

The most startling discovery in the field, however, and one that is highly significant, is the fact that a three-wire strand will vibrate with an amplitude equal and frequently greater than that which occurs in a solid single wire conductor. To fully appreciate what this means, one should consider for a moment the studies on conductor cross-sections, as recorded by Davison[4]. Figure 8 gives the results of this work and, in the writer's opinion, has unintentionally resulted in a considerable misunderstanding of the vibration problem. This tabulation shows the average per cent reduction in amplitude of vibration as found on short specimens having the indicated cross-sections which were suspended from their center by a thin elastic ribbon in a tank containing water which was caused to flow at right angles to the length of conductor. The figures given are no doubt correct, but apply only to the actual test which was applied to these cross-sections.

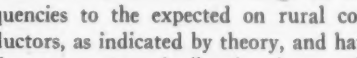


Fig. 8—Effect of cross section on vibration amplitudes as observed in water

Unfortunately, however, conclusions have been drawn with respect to actual transmission lines having the same shapes. A transmission line is an elastic structure under tension suspended in an air stream, a far different vibration system from that used in the Davison experiments where the conductor sample contributed no elasticity whatsoever to the system. Consequently, to conclude, as many have, that a three-wire strand, when used as an actual suspended conductor, will undergo no vibration whatsoever, is quite at variance with facts as well as theory. Any elastic system, such as a stretched conductor constitutes, will vibrate when subjected to periodic forces regardless of its shape, and the amplitude of vibration reached will be that determined by the damping inherent in the system and the relative flexibility of the system.

In fact, according to measurements

[4] "Vibration and Fatigue in Electrical Conductors," A. E. Davison, J. A. Ingles, V. M. Martinoff: A.I.E.E. Convention, June, 1932.

by Mr. Davison, the two-wire strand was supposed to give the same vibrationless characteristic as achieved by three-wires. There are on record several very sad experiences with two-wire strand due to vibration troubles. What is true about three-wire strand is that its inherent damping is greater than that achieved by a solid wire, and that its tendency to vibrate is, indeed, less if one considers the range of forces it derives from the wind. In other words, while the forces derived from the wind on a solid conductor may be sufficient to vibrate it with an appreciable amplitude for a very large portion of the total time, the same wind may produce forces of sufficient magnitude to cause appreciable vibration in the three-wire strand except for a relatively shorter period of the time, so that it takes many more months for a three-wire strand to go through the same number of cycles of stress as might be experienced by a solid wire under the same conditions.

There is nothing, however, to indicate in the shape of the conductor that when it does vibrate, it will not vibrate to large amplitudes, and that so far as abrasion is concerned, the same destructive effects, due to the relative motion of the conductor and the tie wires or insulators, are not to be experienced. We know definitely from samples submitted from the field that three-wire strands can vibrate with destructive effect. What we have also learned, however, is that the three-wire strand will vibrate a much smaller proportion of the total time as compared to the solid wire and in that respect it constitutes a decided improvement over the solid wire for use as a rural conductor. Nevertheless, because its motion may be as large or larger than the solid wire, all necessary precautions must be taken with respect to the proper use of hardware and ties in the handling of such strand, thereby minimizing stresses and reducing abrasion to negligible quantity.

Methods of Minimizing Vibration Damage

Three distinct procedures are in general use for minimizing the effect of vibration on transmission and distribution lines. One method involves incorporation in the construction features of the transmission or distribution strand such characteristics as will eliminate its tendency to vibrate in the wind. This is the reason for the experiments involving the use of cross-sections having triangular shapes or other irregular forms.

A second method that is widely used for eliminating vibration difficulties is the use of dampers in some form or other. The Stockbridge damper is a successful example of this method so far as the heavier types of transmission lines are concerned. While we are continually experimenting with devices of this kind for application to the light rural lines, it is apparent that similar results will be achieved only with the greatest difficulty.

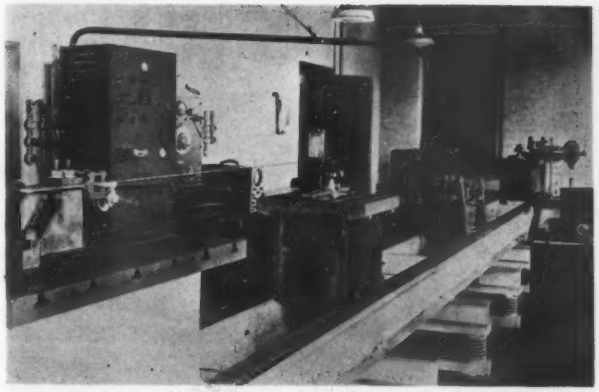


Fig. 9—Vibration fatigue testing machine for rural high strength conductors

A damper device, such as the Stockbridge type, can be used successfully only when its mass is small in proportion to that of the conductor; otherwise, excessive stresses may be induced at the point of application of the damping device itself. So far, this mass ratio has been difficult to achieve in the case of the light rural lines, and while the use of a damping device is theoretically possible, from the practical point of view, it has given trouble in our experiments.

The third method, which so far seems to be yielding the best results, is based on the assumption that the line, being an elastic system, is going to vibrate in the wind. Consequently, it is important that the conductor be so supported and so connected and spliced that the stress concentrations and points of abrasion will be reduced to a minimum. This method involves investigating the curvatures of the conductor during its motion, as well as giving considerable attention to the dynamic features of the hardware and accessories used with the wire, so that high stresses will not be induced due to poor inertia and flexibility characteristics which may be involved in the overall line construction. Such devices for minimizing vibration damage as armor rods, special ties and hardware accessories are included in this method.

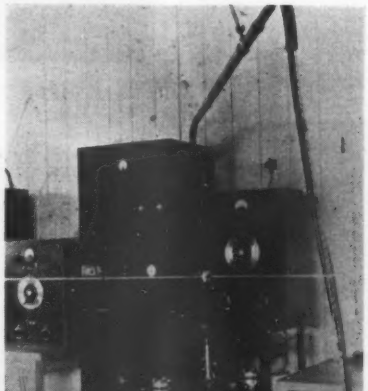


Fig. 10—Electromagnetic vibration motor

American Steel & Wire Company Vibration Fatigue Laboratory

With this full appreciation of the conductor vibration problems as outlined in previous paragraphs, early in 1935 the American Steel & Wire Company established a laboratory for the purpose of studying the characteristics of conductor vibration and developing methods which would serve to minimize and, if possible, to eliminate the fatigue troubles arising from this type of motion.

Figure 9 shows a view of one of the units at the laboratory. In brief, the equipment consists of a mechanical framework and an electrical vibration drive. The mechanical structure is a spring-mounted, built-up structure over 40 feet in length, capable of applying tensions to the line through a system of levers, which have been accurately calibrated. Tensions varying from a few pounds up to several thousand are possible. As may be seen in the photograph, conductor may be dead-ended in any desired fashion, and intermediate tables are supplied upon which hardware, insulators and ties, or other accessory de-

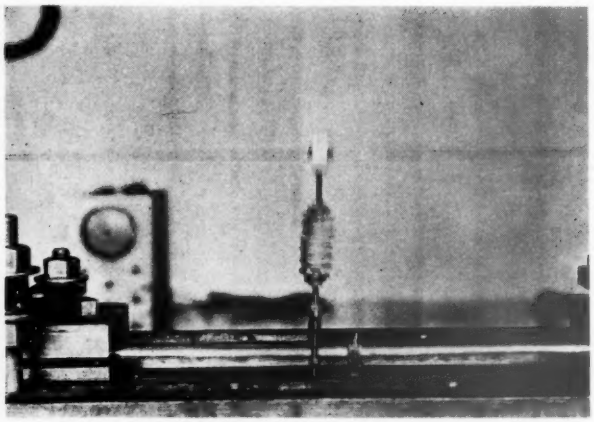


Fig. 11—Vibration motor coupling to conductor

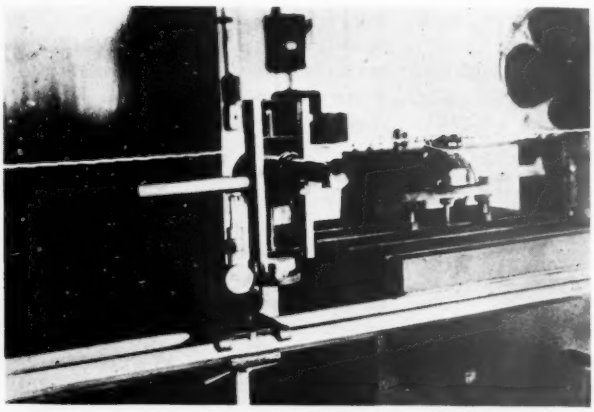


Fig. 12—Cathetometer for measuring vibration amplitudes

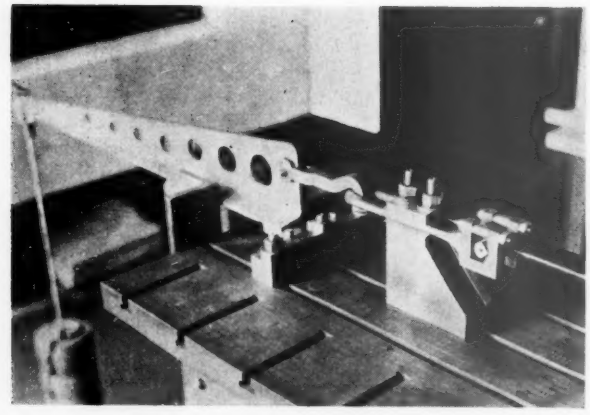


Fig. 13—Method of tension load application for damping measurements

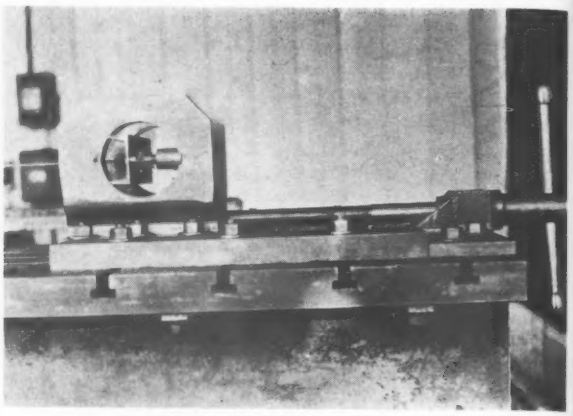


Fig. 14—Load takeup device

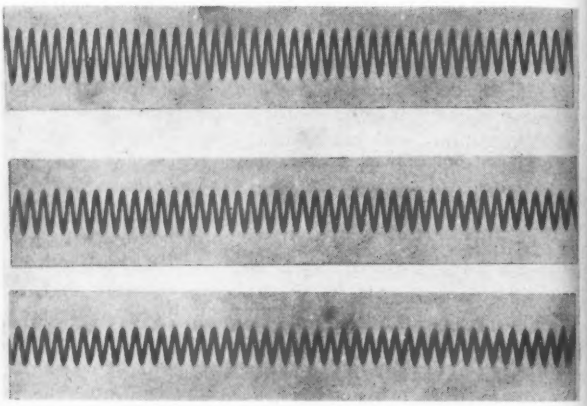


Fig. 15—Die-away curve for solid No. 8, 40% copper covered steel with damper tie

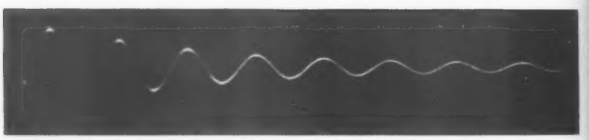


Fig. 16—Die-away curve for typical 7-wire strand

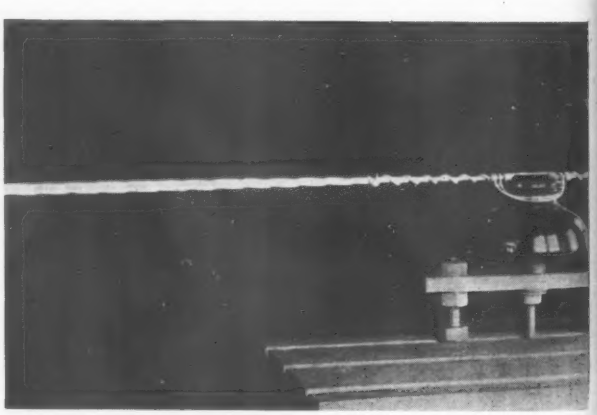


Fig. 17—Rural line tie study

VOX

vices, can be suitably mounted. In the center of the structure is located the vibration motor through which periodic impulses are applied to the conductor; and in the left background may be seen the electrical controls for the vibration motor. Standing beside the near insulator is the U tube of a Stroboscope, a device which has proved of great usefulness in studies of this kind.

Figure 10 is a close-up of the electrical part of the system. In the foreground may be seen the large vibration motor coupled by means of springs to the conductor under test. This motor is in principle similar to a dynamic loud speaker. It consists of a large d-c field in which a moving coil is suspended, this coil containing two windings, one a drive coil, and the second a pickup coil. For certain dynamic reasons, the spindle of the moving coil is spring-coupled to the conductor. This type of coupling permits controlled amplification of the motion of the conductor during vibration, and also eliminates the mass effect at the drive point. For forced vibration the impulses to the drive coil originate in a General Radio oscillator capable of delivering any frequency up to 10,000 cycles a second. This instrument is shown in the background on the right. Its output is delivered to the top panel of the equipment standing at its side. This upper cabinet contains a 40-watt amplifier and all of the controls for the vibration equipment. When extra power is needed, the output of the 40-watt amplifier may be further amplified in the bottom cabinet to over 500 watts before being delivered to the drive coil of the magnet. In tests involving heavily damped items, such as guy strands and wire ropes, these extra amounts of power are necessary. When self-excitation of the conductor is desired at any desired harmonic of the fundamental, the input to the drive coil originates in the pickup coil. The output of this coil is passed through suitably adjusted filters to give the desired harmonic and amplified, as in the case of forced vibration, before being sent to the drive coil.

There are controls available which make it possible for the equipment to automatically shut down in the event of any failure or change in the vibrating system. A clock in the mechanism automatically records the time of vibration, and the frequency is determined from a previous calibration. There are switches which make possible the obtaining of die-away curves on an oscillograph not shown in the picture so that the damping characteristics of a system involving conductors, hardware or ties may be also studied.

Figure 11 illustrates the operation of the spring coupling from the moving coil of the magnet to the conductor. The amplification of motion is quite noticeable, and careful observation shows that the stresses at the drive point have been reduced to such a value that the loop, which includes this point, hardly differs from any other loop in the vibrating line.

Amplitude measurements are made, as shown in Figure 12, by means of an accurately calibrated cathetometer. The amplitude of vibration is adjusted so that the maximum motion in the first loop clear of the insulator and tie being investigated is a desired amount. When this has been accomplished, the electrical units are locked so as to maintain this motion during normal operation. If for any reason a failure takes place or the tension in the conductor increases or decreases, thereby affecting this amplitude of motion, the equipment will automatically shut down.

Damping Tests

To study the damping characteristics of a given conductor and its system of ties, the line is dead-ended, as shown in Figure 13, on a knife edge. This figure also illustrates the manner of applying load and the means by which a conductor terminal is locked into position if it is so desired.

Figure 14 shows the other end of the line when set up for damping tests. The small knife edge is not visible, it being obscured by an adapter which has been used for converting the knife edge seat for another experiment. The picture shows clearly the take-up screw by means of which the load applied to the lever system can be brought to its full value.

It is interesting to compare the die-away curves obtained for a typical solid rural conductor even though treated with a so-called damper tie, which involves a preformed wire placed around a main conductor, with that obtained from a typical strand as used in railbond construction. Both tests were made at frequency of 49 cycles per second.

Figures 15 and 16 enable us to make the comparison. In the case of the strand, it is necessary to increase the speed of the oscillograph in order to get a readable trace. From numerous tests which we have made, it appears that the incorporation of damping devices in rural lines is possible only with great difficulty. We have found that either a so-called damper does not effectively dampen the motion, or else, if it is effective, it introduces such severe points of abrasion, due to friction, that it is questionable whether the conductor may not be damaged to a greater extent than ever before. We are still at work on the possibility of developing suitable dampers for rural lines. However, as outlined, the problem is a difficult one with these light weight conductors, and requires careful study and testing before definite recommendations can or should be made.

Rural Line Tie Studies

The most valuable and interesting studies so far made on our equipment have been in connection with the development of ties for rural conductors. Figure 17 is a close-up of a tie test. By means of the stroboscope and other devices, it has been possible to observe the inner action of the tie wires and conductor, as well as accurately determine the points of maximum stress concentration as they occur in either the tie or the conductor material. The tie shown in this picture contains several bad features, although it does represent at least one step in the right direction. Very early in our studies, it was found that the lateral distortion of the conductor resulted in a stretching which was so minute, so far as motion was concerned, that it could only be measured with instruments. Nevertheless, this stretching or longitudinal motion of conductor takes place at an extremely high frequency; in fact, at a frequency just double that of the lateral vibration. This is because the conductor stretches whether the lateral motion is at the extreme top or bottom of its swing. Consequently, where the bare conductor passes over the top of a typical porcelain insulator, abrasion of the most severe type takes place. This has been noticed many times in the field on conductors removed from insulators, and is now being quantitatively and qualitatively studied in our laboratory.

Our studies indicate very definitely that the amount of relative motion involved in vibration phenomena does not have to be of any significant magnitude to cause damage. The frequencies involved are so great that the action is of the most severe nature. This is not hard to appreciate when one frequently meets with abrasions of this kind under the heads of tightly fastened bolts on machinery that is apparently rigid. It becomes at once apparent that for the maximum life and best practice, an armored

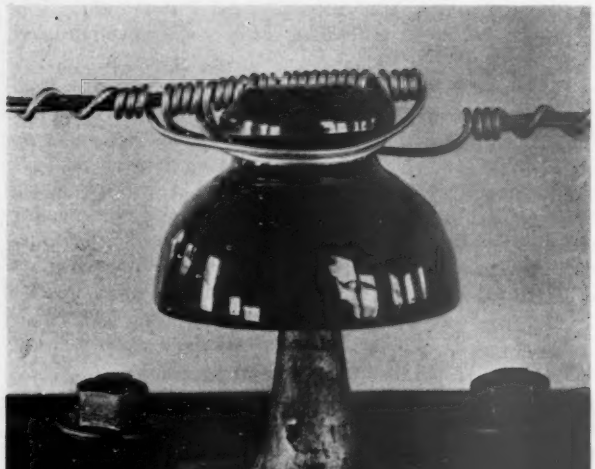


Fig. 18—Conductor fatigue failure resulting from poor tie system

Fig. 19—A. S. & W. "T-tie"

Fig. 20—A. S. & W. "T-tie" with insulator removed

tie is the most desirable, regardless of the conductor material. Such a tie is shown in the figure.

Further studies indicated that the so-called "simple" ties, which have heretofore been specified in great quantities, were made in such a fashion that the tie wire as it passed from the insulator to the conductor was severely cut by the lip of the insulator. It was an outcome of investigations of this nature that led us to make a recommendation to an insulator manufacturer through one of the private utilities which resulted in a modification of the design of this feature of a pin type insulator, thereby effecting a considerable improvement so far as abrasions to the tie wire concerned. We also learned that the common types of ties were made in a manner that had the tie wires cross one another in the vicinity of the conductor so that in the ensuing vibration, these wires further abraded one another, frequently resulting in early failure of the tie wire.

By far the most detrimental characteristic of the prevailing "simple" ties was the way in which they held the conductor to the insulator. For the most part, the tie wire was brought up from under the lip of the insulator up over the conductor and immediately returned to the insulator, referring specifically to the top tie. In such an arrangement, the conductor during its vibration can move downward without severe restraint, and will take a natural easy curvature over the top of the insulator. However, on the upward vibration, the loop of the tie wire firmly fixes the point at which it contacts the conductor. Consequently, the conductor bends upward, not in a smooth curve from the center of the insulator, but in a rather sharp bend right at the first snubbing loop. This was measured and observed by us time and again, and without actually running a system of conductor and tie to failure, it was possible to predict long in advance just exactly where the point of fracture would take place. Such defects in a tying system produce fatigue failures in the conductor, as shown on Figure 18. This tie is another of a long series with which experiments were made in an effort to overcome the various defects mentioned above. While it offered some improvements, it was still far from satisfactory.

After numerous trials and experiments involving the use of tie wires of both copper and galvanized steel, made up according to all manner of systems, the tie shown in Figure 19 was finally evolved. It represents a definite scientific approach to the tie problem, and is far more than a random collection of twists and loops. In the first place, the tie wire where used is a special galvanized soft steel wire having a small diameter and capable of complete manipulation without tools. It has been specially prepared for tying purposes and it has a fatigue life far in excess of any copper or copperweld wire used for similar purposes.

Two relatively short pieces of this wire are used for making the tie indicated, and many thousands of such ties have been made on existing rural distribution systems. The procedure, once learned, can be readily followed by any lineman, and those who have had the experience of making these ties find them entirely satisfactory and easy to make. As will be noted, the armoring feature is present. Five loops of tie wire have been placed adjacent to the insulator, in order to produce a long, gentle slope of the tie wire from the conductor to the insulator. This avoids contact with the lip of the insulator, and has completely removed any evidence of abrasion on the tie wire at this point. Two loops are then placed between the two wires which go down from the conductor to opposite sides of the insulator, thus definitely separating them from rubbing on one another during motion.

The most important feature of this tie, however, is the manner in which the wire from the insulator is wound on to the conductor, without immediately returning to the insulator, thus avoiding the detrimental snubbing loop found in other ties. By actual test and observation during high frequency vibration, it is apparent that this conductor, in its downward movement as well as in its upward movement, slopes from the center of the insulator with the gentlest curvature; avoiding at any point where the tie wire contacts the conductor, the presence of any stress concentrations as have hitherto existed in other tie systems.

Figure 20 shows more clearly what has been accomplished. The insulator has been removed and the separation of

the tie wire, as well as the configuration of loops, is more clearly seen.

To demonstrate more quantitatively what has been accomplished with this tie, one need only consider the following figures. With the conductor shown, which is a galvanized steel-copper composite three-wire conductor, a tie made of galvanized steel wire in the usual manner, containing the several detrimental features previously discussed, would result in a fatigue failure of the conductor in about 10,000,000 cycles of stress. In these experiments the test used consisted of vibrating the line at 165 cycles per second, through a total amplitude of .2 inch with 25 per cent breaking load applied to the conductor.

In making the tie shown in the figure —which we have chosen to call a "T-tie"—and applying the same test described above, we have vibrated similar conductors through 50,000,000 cycles of stress (representing day and night operation through one week) without failure in the tie wire or in the conductor.

It is well to remember that so far as conductor fatigue is concerned, the point of tying represents one of the most serious problems involved. It is at this point that the normal stringing stresses are raised to a point where they become serious, and are likely to induce fatigue failures, as described in an earlier section of this paper. These concentrations arise from points of sharp curvature and restraint. Consequently, the system of tying must be given considerable thought. We are met with two important features of the system to be considered. The first is the material of which the tie shall be made, and the second is the tying system itself. If the material is one having a low endurance limit, such as annealed copper wire, or copper covered steel, a fatigue failure of the tie wire itself is easily obtained, even though the system of tying used may be of the best—or at least equal to that described in the previous slide. On the other hand, one might use a tie wire having a low endurance limit, and a tie system having objectionable features. The net result is a combination having the worst characteristics of both, and it becomes a matter of debate whether the conductor or tie wire will fail first. In some cases we have had both fail within a few seconds of each other.

To illustrate this quantitatively, it is interesting to point out that a No. 8-A Copper Covered Steel conductor, tied in the manner prescribed for that conductor, using annealed No. 8 copper wire, will show a conductor failure in less than 2,000,000 cycles, when subjected to the 165 cycle test described above. If this same annealed copper wire is tied about the conductor in the manner used for making the so-called "T-tie," the life of the conductor can be prolonged to as many as 8,000,000 cycles, but at the expense of two or three tie wires, which will have fatigued and have had to be replaced in order to continue the test. If a high endurance tie material, such as galvanized steel wire is used with a poor tying system, fatigue life of the system will be determined by the conductor material. In our experience we have yet to produce a fatigue failure of such a tie wire. Obviously, if a copper conductor is used, the conductor life will be low, whereas with a steel composite conductor, the fatigue life is correspondingly higher, being some 10,000,000 cycles as in the experiment described above.

The ultimate is achieved when a good tie system is made, using a tie wire of the highest endurance limit. This is what has been done and recommended for the all-steel conductor and the steel composite conductors. In this case steel galvanized tie wires are twisted about the conductor in the manner shown in the "T-tie." The results achieved have already been described. It is not our intention to leave the impression that the final word in ties has been reached. On the contrary, we feel that the objective of such studies is the development of a purely mechanical device which will do away with the archaic procedure of twisting one wire about another in order to hold it to an insulator. We have studied some attempts of this former nature, and have given considerable thought to a development of our own. So far, results have been disappointing, because none of the devices tried have lacked some objectionable feature. While they may simplify the time element in fastening a conductor, they introduce stress concentrations which may not be obvious until the tests are performed.

Abrasion Studies

As a final point of importance and interest in our tie studies, some discussion concerning the matter of abrasion is in order. During our early work with copper conductors and ties made of copper wire, we found, upon examination, that during the period of vibration the insulators would be covered with a fine, reddish dust. We soon found this to be copper which was being worn away from the tie wires or the conductor during the tests. It was further made obvious to us from samples sent in from the field that abrasion was a very serious factor in the case of copper surfaces in contact with one another. A high coefficient of friction appears to exist between such copper surfaces, and this fact appears to be verified by other researches on intermetallic boundary friction. Since abrasion weakens the surface of any material, and since this is the very place where stresses are highest during vibration, the combination of circumstances is very serious, so far as fatigue life is concerned.

Figure 21 shows the results of one of our early experiments. This was done at a time when considerable vibration trouble was being experienced with solid No. 8 copper covered steel conductors, tied with annealed copper wire. If one looks carefully under the ends of the

Fig. 21—Abrasion characteristics of copper surfaces in contact

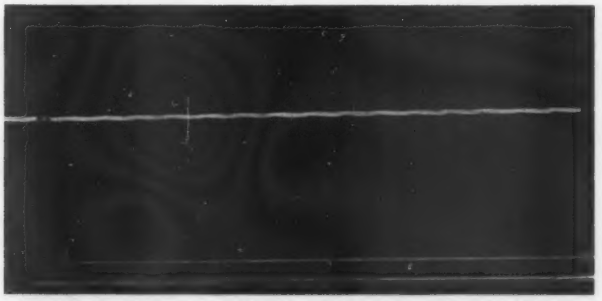


Fig. 22—Abrasion characteristics of zinc coated surfaces in contact

broken tie wire, a spot may be seen where the copper has abraded through the conductor surface, exposing the steel core. Samples submitted to us from the field have shown that this is not an unusual circumstance, and is frequently reported by numerous utilities. Copper wires have been known to be so badly abraded, in some types of hardware, that they virtually disappear.

When dealing with galvanized steel surfaces, as in the many experiments described, a layer of zinc, whether applied to the steel tie wire or to the copper and steel wires in a composite conductor, or the steel wire alone in an all-steel conductor, practically eliminates the abrasion problem. After as many as 50,000,000 cycles under severe vibration conditions, such conductors and ties, when examined closely for wear, showed little, if any, signs of abrasion. All that appears is a high polish on the zinc surface. This is not strange, inasmuch as zinc is a comparatively hard, slippery metal, frequently used as a base for bearings. At no time were the insulators covered with any products of wear, as in the case of the copper-surfaced conductors.

Figure 22 shows a portion of a steel composite conductor, in which the copper as well as the steel wires are covered with zinc. This is a No. 8 conductor, which was tested for 50,000,000 cycles with a galvanized steel tie applied at the portion indicated in the photograph. Close observation shows no removal of the zinc due to abrasion, after 50,000,000 cycles of stress, whereas the damage shown on the copper conductor in the previous picture, represents the condition after slightly over 1,000,000 vibrations.

We have by no means completed our work, and have only begun to consider the numerous other items which are used with rural conductors. Work is now going on in connection with the proper use of sleeves, splices, connectors, and various types of hardware. Proper equipment has made possible a field for study which has been somewhat neglected in the past, and what we are accomplishing seems to have some value, not only to ourselves as conductor manufacturers, but also to the utility user and the hardware manufacturer.

The steel industry has been extremely interested in the application of steel in the form of the steel-copper composite conductor, or the all-steel conductor for electrical purposes. It has been our feeling that so long as the electrical industry finds a place for the electrical properties of these materials, it is our primary concern to discover and recommend the best methods for their use, so that failures from such enemies of continuous service as conductor vibration will be overcome in the case of these applications of steel. It is hoped, therefore, that the information given in this paper will not only prove of general value to the Transmission and Distribution Committee, but will also show the efforts which are being made to make the steel-copper composite conductor, and the all-steel conductor a valuable and economical tool for use in rural distribution.

Third National Accounting Conference to Be Held at Chicago in November

THE third annual National Accounting Conference of the Edison Electric Institute will be held at the Edgewater Beach Hotel, Chicago, Illinois, November 13, 14 and 15, 1939.

The Conference is being arranged by the General Accounting Committee of the Edison Electric Institute through its Planning Committee, composed of the following members:

G. H. Bourne, The Commonwealth & Southern Corp., New York, N. Y.; K. C. Campbell, The Detroit Edison Company, Detroit, Mich.; A. Corson, The United Gas Improvement Co., Philadelphia, Pa.; W. C. Fisher, Consolidated Edison Company of N. Y., Inc., New York, N. Y.; A. M. Hartogensis, Ebasco Services, Inc., New York, N. Y.; Franklin Heydecke, Public Service Electric & Gas Co., Newark, N. J.; J. M. Kramarsik, The Connecticut Light & Power Co., Hartford, Conn.; and Miss Mae B. Woods, Edison Electric Institute, New York, N. Y.

In addition to the above, Bernard S. Rodey, Jr., Chairman, and Merle Rainey, Secretary of the General Accounting Committee will assist the Planning Committee.

It is planned this year to allocate somewhat less time to the general sessions so as to devote the main effort of the conference to specialized Committee meetings. This is believed to be in line with the desires of a great majority of utility accountants, many of whom come to these gatherings with specific problems affecting their companies.

To meet their needs, much work has already been done by the various Committee Chairmen and Vice-Chairmen to organize the presentation of subjects in their respective fields. Active and gratifying interest is being shown in this effort of preparing a diversified program that will not only be beneficial to those in attendance, but also to the industry as a whole.

Tentatively it is now thought the full day Monday, November 13, should be devoted to meetings of the several committees studying specialized accounting matters. The morning session of these meetings are for committee members only but will be open in the afternoon to industry representatives by invitation or upon request to the respective chairmen. Only the forenoon sessions on Tuesday and Wednesday are at present being considered as general sessions; the afternoons being considered as additional time for meetings of the specialized groups.

The industry is always interested to get the viewpoint of those who look at its problems from a new angle and can offer new channels of thought. Therefore, negotiations are now under way to obtain distinguished speakers from outside the industry. They are to speak at the General Sessions and at the informal dinner on Tuesday night.

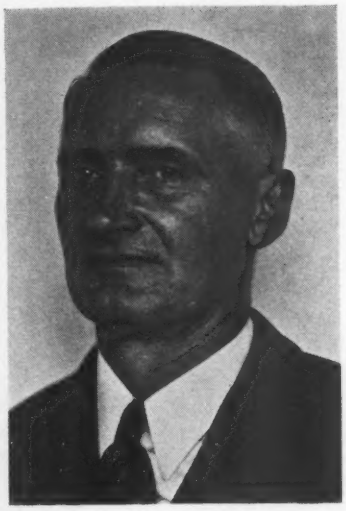
The Planning Committee is now actively at work on the Conference, assigning the many interesting and important topics. Any suggestions from members of the committees, or any of the companies, as to the selection of subjects will be gratefully received by the Planning Committee.

The past year has brought many new accounting problems to the fore, particularly in relation to governmental regulation and taxation. These new problems in addition to the mounting accounting costs, interpretation of accounts, and questions arising in the determination of costs and depreciation problems, afford a real opportunity for accountants and others interested to get together for a more mutual understanding and exchange of ideas. This year's Conference bids fair to become one of the most interesting ever held and the Planning Committee looks forward to a record attendance, both as regards the number of individual accountants and of companies represented.

The September issue of the BULLETIN will contain additional information regarding the 3rd National Accounting Conference and the completed program will be shown in the October issue.

The Effect of Temperature Upon Bronze Valves

By F. P. Tierney, *Engineer* and W. C. Thompson, *Chemist*
of Testing Department of Northern States Power Company, Minneapolis, Minn.



MR. TIERNEY

IN the power industry where the demands on metals are unusually severe, the properties of metals under stress at elevated temperatures are of vital importance in the interests of safety and uninterrupted service. The investigation described in this paper, which concerns the effect of high temperatures upon bronze valves, was prompted by the discovery of defects in gate valves which had been exposed to 425° F. over a period of 14 years. An extraordinary opportunity was afforded to study the influence of prolonged temperature exposure upon the structure and mechanical properties of bronze, and to supplement the limited information available in the literature which was based on comparatively short time experiments.

In August, 1938, the bodies of two 1¼-in. bronze gate valves on the steam equalizing line of a boiler feed water regulator cracked when workmen attempted to open connections on the line in which the valves were located. The valves, which had been installed in 1924, had been in operation approximately 90 per cent of the time at 425° F. and 310 lb. per sq. in. When they were submitted to a cursory examination and to certain mechanical tests, it was disclosed that the metal was of a brittle nature.

Since it was suspected that the brittleness of these two valves was caused by a temperature effect due to the type of service, an examination was made of another valve (from the same station) of identical make and type which had been exposed for the same period to not over 100° F. Tests similar to those made on the 425° F. valve materials indicated that the metal in the 100° F. valve was much more ductile than that in the valves which failed.

Chemical analyses of the metal in the valves showed them to be commercially identical in composition. Microscopic examination disclosed that the structure of the metal exposed to a maximum temperature of 100° F. differed markedly from that exposed to a temperature of 425° F. The former exhibited the normal structure of bronze castings of this type, but the latter was abnormal in such a manner as to indicate that its altered structure was due to changes which took place while in service rather than to any commercial variation in casting practice.

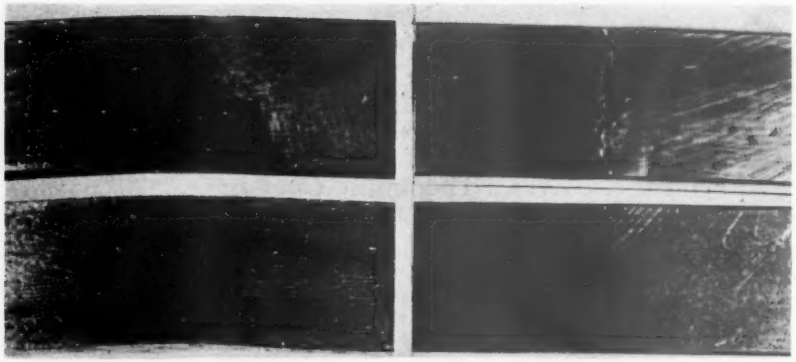
In order to confirm this view it was decided to examine a sufficiently large number of valves which had been exposed to each of several temperatures. There were available in this plant valves of identical make and type with identical periods of service, which had been exposed to temperatures of 100°, 320°, 425° and 700° F. The valves removed for examination included at least three which had been in service at each temperature. Since those of each temperature class were similar in properties and test results, four were chosen as representative for consideration in this report. The data on these valves are shown in the following tabulation:

Valve No.	Type	Size Inches	Service	Temperature Deg. F.	Pressure lbs. per sq. in.
1	Gate	1½	Cold water	100	200
2	Gate	1¼	Hot water	320	310
3*	Gate	1¼	Saturated steam	425	310
4	Globe	¾	Superheated steam	700	300

* Broken in situ when wrench was applied.

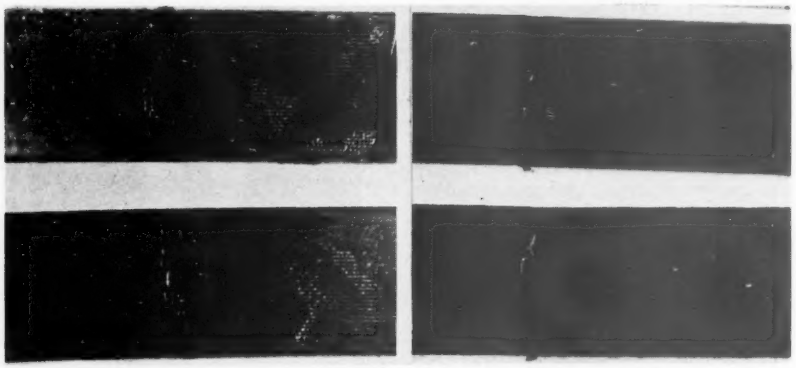
The size and the design of the valves was such that pieces could not be obtained for making the usual brittleness tests or for standard tensile tests, but it was possible to cut specimens 3/32 in. thick, ⅜ in. wide, and 2 in. long. These specimens were submitted to a bending test by clamping them in a vise and applying a bending force with an accurate micrometer screw at exactly 1 in. from the face of the vise. Figure 1 shows the test pieces after bending. No cracks were apparent in the material from valve 1 (100° F.) when deflected 0.6 in., but there was slight cracking in that of valve 2 (320° F.) when bent the same amount. The valve 3 (425° F.) specimens cracked when the deflection was 0.29 in. and the valve 4 (700° F.) specimens broke at a deflection of 0.19 in. These results prove that the higher the temperature to which the valves had been exposed, the more pronounced was their brittleness.

MR. THOMPSON



Valve 1 (100° F.)
Deflected 0.6 in.
No cracking

Valve 2 (320° F.)
Deflected 0.6 in.
Slight cracking



Valve 3 (425° F.)
Deflected 0.29 in.
Pronounced cracking

Valve 4 (700° F.)
Deflected 0.19 in.
Cracked through

Fig. 1—Test pieces after bending (enlarged 2½ times)

As previously stated, standard test specimens could not be cut from the valves, but comparative tensile strength tests were made on the most suitable pieces obtainable. The results were as follows:

Valve No.	Temperature Deg. F.	Tensile Strength at 70 Deg. F.
1	100	36,000 lbs/sq. in.
2	320	34,800 lbs/sq. in.
3	425	28,800 lbs/sq. in.
4	700	Specimen not obtainable

These results indicate that the tensile strength decreased as the temperature to which the metal had been exposed increased.

The manufacturer of these four valves rated the tensile strength of the alloy as 33,735 lb. per sq. in. at 750° F. and recommended them for service with superheated steam at pressures up to 300 lb. per sq. in. and with total temperature up to 600° F.

Analyses of the valve metals showed the following percentages of copper, tin, and zinc:

Valve No.	1	2	3	4
Copper	85.69	84.37	85.08	85.00
Tin	12.34	12.35	11.62	12.45
Zinc	1.85	3.24	3.13	2.31

The material of these four valves approaches that of Government Bronze (B10) in composition.

For purposes of comparison, parts of the A.S.T.M. (American Society for Testing Materials) standard specifications [1, 2, 3] for the following bronze alloys are included:

A.S.T.M. Designation	B10	B60	B61
Alloy Name	Government Bronze		Steam Bronze
Date standard adopted	1918	1928	1928
Date discontinued	1936	....	....
Tensile strength,* lbs/sq. in.	30,000	38,000	34,000
Elongation in 2 in.* per cent	14	22	22
Analyses, in per cent:			
Copper	86 to 89	86 to 89	86.5
Tin	8 to 11	7.5 to 11	5.5 to 6.5
Zinc	1 to 3	1.5 to 4.5	2 to 5

* Minima physical properties at room temperature.

Fig. 2—Material of Valve 1 (100° F.) after stress, showing the brittle nature of the eutectoid. Etched with $NH_4OH + H_2O_2$

The A.S.T.M. was cognizant of the fact that a high tin alloy was not satisfactory for castings to be used at temperatures above 500° F. as early as 1918, when its specifications for B10 included a clause to this effect. This limitation was not introduced into the standard specification for B60 until 1936. In the same year the A.S.T.M. stated that B61 was suitable for applications which involved temperatures of 500° F. The trend of these specifications is toward a lower tin content in bronze for high temperature use.

When bronze cools from the molten state, the portions that first solidify, called the cores, are relatively rich in copper; and the proportion of tin in the remaining melt is consequently increased. As solidification proceeds, each succeeding portion to solidify is richer in tin. The resulting metal has a characteristic dendritic or tree-like structure. The grains are composed of a yellow matrix of tin in copper and an imbedded grayish blue eutectoid. This eutectoid is brittle and, in contrast to the more ductile matrix, is high in tin content.

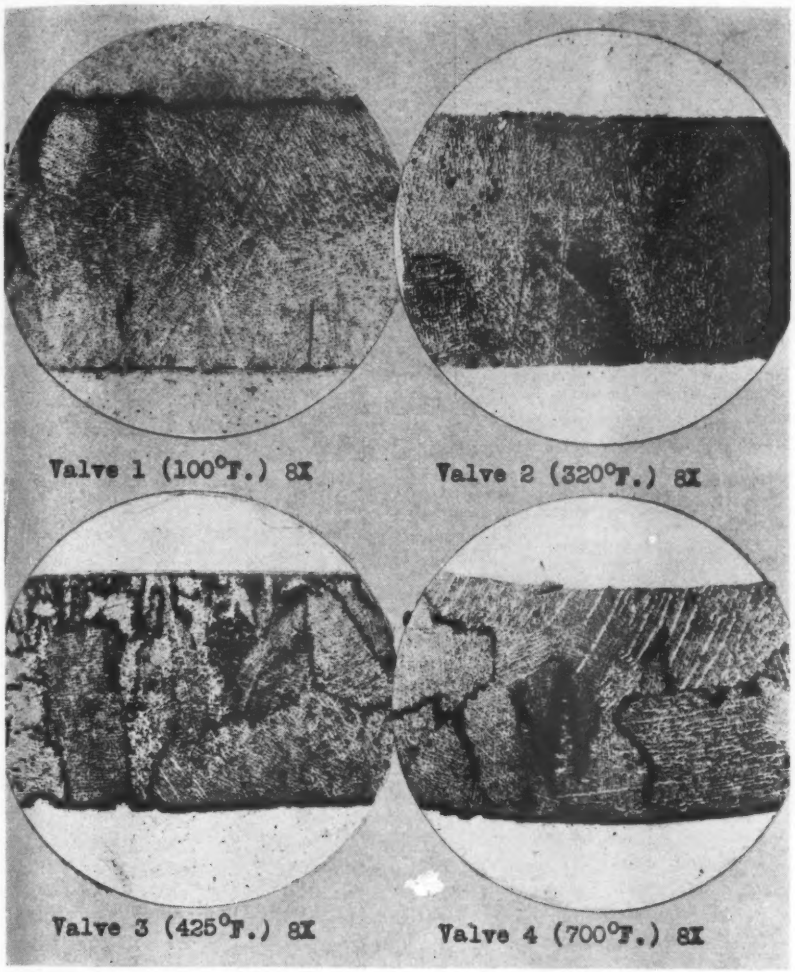


Fig. 3—Macrographs indicating the gradation of eutectoid formation in valve materials exposed to service temperatures for 14 years. Etched with $NH_4OH + H_2O_2$

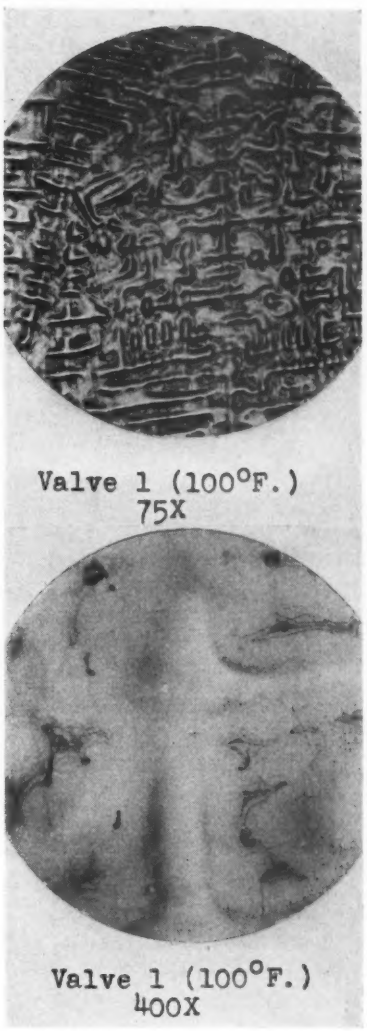


Fig. 4—Micrographs of the valve materials, showing eutectoid formation. Etched with $NH_4OH + H_2O_2$

The characteristic structure of a typical bronze of 12 per cent tin content as revealed in the 100° F. valve is illustrated by Figure 4. At 75 magnifications its dendritic nature is very apparent. The dark areas are the copper-rich cores. Close inspection will disclose the presence in the matrix of disconnected angular "islands" of the tin-rich eutectoid about midway between the cores. The distribution of the eutectoid in the matrix is clearly shown at 400 magnifications.

The brittle nature of the eutectoid is illustrated in the micrograph at 400 magnifications (Figure 2) of the metal in the vicinity of the break in a stressed specimen from the 100° F. valve. It will be noted that cracks appear in the eutectoid only, and not in the surrounding more ductile matrix. These cracks are parallel to each other and are perpendicular to the direction of stress. The amount and the distribution of the eutectoid particles in this material are normal for bronze castings of this tin content which have not been exposed to high temperatures.

In a study of the effect of elevated temperatures upon tin bronze, Bolton [4] exposed B60 alloy (10 per cent tin) under stress to constant temperatures of 500°, 550°, and 600° F. for approximately 1700 hrs. With regard to the lowered strength and ductility of these specimens, he states that the eutectoid "acts as an embrittling agent at elevated temperatures and bronzes containing this eutectoid should be viewed with suspicion for application at 500° F. and above." He further states: "Microscopic study suggests that this embrittlement is caused by the formation and to some degree possibly to penetration of the eutectoid along the grain boundaries. This condition becomes very apparent at 600° F."

It would seem probable that if a bronze containing 10 per cent tin exhibited eutectoid formation when exposed to 500° F. for a comparatively short period, that a bronze of higher tin content might show similar eutectoid formation when exposed to a somewhat lower temperature for 14 years. The correctness of this supposition is substantiated later in this paper by micrographs which show the formation of eutectoid at grain boundaries in the 320° F. and the 425° F. valve materials. A definite gradation of eutectoid formation in relation to exposure temperature is also shown. This relationship is in agreement with the results of

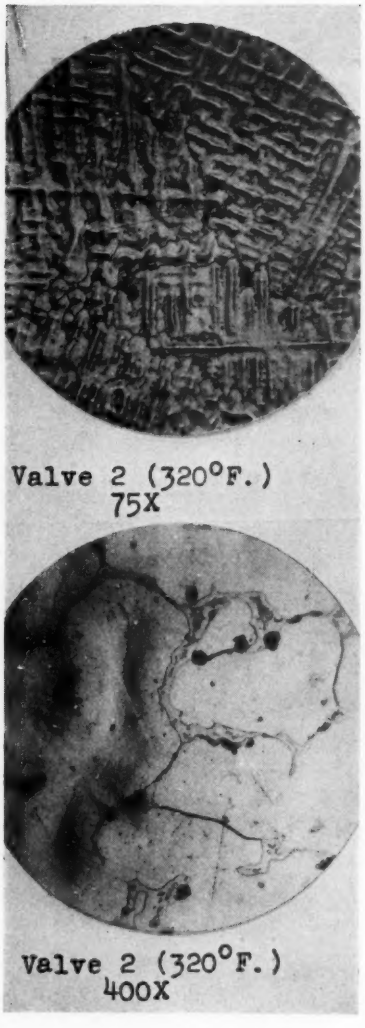


Fig. 5—Micrographs of the valve materials showing eutectoid formation. Etched with NH_4OH + H_2O_2

Fig. 6—Micrographs of the valve materials showing eutectoid formation. Etched with NH_4OH + H_2O_2

Fig. 7—Micrographs of the valve materials showing eutectoid formation. Etched with NH_4OH + H_2O_2

the bend tests, in which the brittleness of the metal increased with the temperature.

Attention is called to the macrographs at 8 magnifications of etched specimens (Figure 3), which illustrate the extent of the eutectoid formation at the grain boundaries. The metal from the 100° F. valve shows the dendritic structure with no definite grain outlines. That of the 320° F. valve at this magnification is similar in appearance. The macrographs of the materials in the 425° F. and the 700° F. valves exhibit a temperature effect which is evidenced by wide dark bands, either partially or completely surrounding many of the grains. That these bands are located at the grain boundaries can be readily observed by noting the change in orientation of the dendrites at the bands.

The micrographs at 75 and 400 magnifications show in more detail the gradation and structure of the eutectoid formation. The 100° F. valve metal (Figure 4) has a normal amount and distribution of eutectoid particles for commercial bronze of this tin content as cast.

Figure 5, which represents the 320° F. valve, shows a slight increase in the eutectoid and a tendency for it to be continuous rather than isolated in "islands," particularly at the grain boundaries.

The formation of the eutectoid at the grain boundaries of the metal from valve 3 (425° F.) is so pronounced that it is visible in an etched specimen without magnification. The presence of dark bands at grain boundaries has been noted in Figure 3 at 8 magnifications. Although these bands appear solid at 8 magnifications, examination at 400 magnifications (Figure 6) shows them to be straited with threads of bluish gray eutectoid. It appears that where the eutectoid formation has "robbed" the adjacent metal of some of its tin, it has left this metal relatively high in copper content, which gives this area its dark appearance.

As would be expected the 700° F. valve contains much more embrittling

(*Continued on page* 424)

Personnel of E. E. I. Committees for 1939-1940

APPOINTMENTS to E.E.I. Committees for the administrative year 1939-1940 have been made by President Kellogg, with the exception of the Committees under the General Sales Committees whose membership will be announced in a subsequent issue.

The committees which now have practically complete personnel include the following: Operating; Accident Prevention; General Accounting; Classification of Accounts; Customers' Relations, Commercial Accounting and Collections; Depreciation; Plant Accounting and Records; Purchasing, Stores and Transportation; Electrical Equipment; Hydraulic Power; Insurance; Prime Movers; Prize Awards; Rate Research; General Sales; Statistical; Transmission and Distribution.

Several of the committees have already fixed dates for their fall meetings, as listed in the Convention and Meetings section of the BULLETIN, and others will be announced shortly.

The personnel of the Operating Committee is listed on the inside of the back cover of the BULLETIN. Personnel of other committees follow:

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DWIGHT DOUGLAS, The Hartford Electric Light Co., Hartford, Conn.
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A. T. HUTCHINS, The Commonwealth & Southern Corp., Birmingham, Ala.
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Inductive Coordination

(*Continued from page* 400)

neutral case. (This partially explains why the influence may go down when a uni-grounded neutral system is converted to a multi-grounded neutral system.)

This is a very much simplified explanation of what actually happens on a rural circuit but it does bring out one of the very important principles. The actual case is usually much more complex since it involves three-phase as well as single-phase circuits; loads may have some effect, but, perhaps most important of all, propagation and resonance effects may occur. The complete story of these effects is too long to be included here and anyone interested should go to the more extensive literature on the subject[1, 2].

It may be pointed out, however, that for the longer rural circuits, the correct representation requires a number of elements like those in Figs. 2 and 3 in series and that for such a condition the inductances and capacitances may become resonant at some particular frequency, with a relatively large increase in the magnitude of the voltage or current or both at that frequency. Also, the capacitances of the line and the inductance of the supply transformers may become resonant at some particular frequency with similar effects.

BIBLIOGRAPHY

(1) Engineering Report No. 40 of the Joint Subcommittee on Development and Research of the Edison Electric Institute and Bell System, entitled "Inductive Coordination of Rural Power and Telephone Systems." This is a complete report of the experimental and theoretical work done by the joint subcommittee on noise frequency inductive coordination in rural areas.

(2) A.I.E.E. paper entitled "Noise Coordination of Rural Power and Telephone Systems" by H. W. Wahlquist, Edison Electric Institute and T. A. Taylor, Bell Telephone Laboratories, Inc. This paper was presented at the 1938 summer convention of the A.I.E.E. and was published in the November, 1938, issue of "Electrical Engineering." It contains a comprehensive discussion of the subject but does not have as much detailed data as Engineering Report No. 40.

(3) Engineering Report No. 32 of the Joint Subcommittee on Development and Research entitled "Relative Interfering Effects of Different Single-Frequency Noises in Telephone Circuits."

(4) Engineering Report No. 33 of the Joint Subcommittee on Development and Research entitled "The Telephone Influence Factor of Supply System Voltages and Currents."

(5) A.I.E.E. paper entitled "Measurement of Telephone Noise and Power Wave Shape" by J. M. Barstow and P. W. Blye, Bell Telephone Laboratories, Inc., and H. E. Kent, Edison Electric Institute; published in Electrical Engineering, December, 1935.

(6) Engineering Report No. 16 of the Joint Subcommittee on Development and Research entitled "A Method of Estimating Noise in Open-Wire Toll Circuits." This report contains curves of "Coefficients of Induction."

Blossom Appointed Secretary of Indiana Association

R. E. BLOSSOM of Indianapolis has been appointed to the newly created full-time secretaryship of the Indiana Electric Association by C. B. Calvert, association president.

Mr. Blossom will make his headquarters in the Traction Terminal Building, Indianapolis, but his work will take him to all parts of the state in which members of the association supply electric service.

Previous to his appointment as secretary, Mr. Blossom had been manager of radio station WFBM and was merchandise manager of the Indianapolis Power and Light Company from 1932 until 1937, also handling the company's advertising for more than four years. He was engaged in sales promotion and organization work prior to joining the Indianapolis company, having been with the Prest-O-Lite Company, Inc., from 1909 until 1925.

Federal Control of Utilities

(*Continued from page* 382)

revenues were reduced by the amount of the so-called overcharge, then not only could no interest or dividends be paid, but operating expenses would have to be reduced materially to make ends meet. This reduction would have to come out of wages, since the cost of taxes and fuel are not subject to control.

It is indeed surprising that with such unimpeachable evidence at hand there are still some people who believe the absurd statements of Congressman Rankin that charges above the TVA rates constitute robbery; and because of such belief continue to advocate the entry of municipalities into the field of providing electric service.

News from MKB

(*Continued from page* 392)

listed among the prize winners in these contests. Five additional awards of $5 each were made.

This contest was the second in the series of four conducted by the Bureau this year. Only requirement for entry is a letter on the subject "How I Sell Electric Water Heaters." It is open both to utility and dealer salesmen of electric water heaters.

The Bureau's contest for window displays of electric water heaters which ended June 30 went to Atlantic City Electric Company at Bridgeton, New Jersey, the accompanying $100 award going to I. C. Dixon. The second prize of $50 went to N. A. Zanzig, Wisconsin-Michigan Power Company, Appleton, Wisconsin.

The Bureau's "Scotch Eskimo" campaign for electric refrigeration, used successfully by more than fifty utility companies since the first of January, will be continued throughout the remainder of the year. Companies that have used it have reported gratifying consumer interest and sales increases.

The Bureau's national cooperative campaign for electric roasters, launched last spring, also continues throughout the year. It will be reinforced this fall with intensive magazine advertising during the peak sales months in *McCall's, Woman's Home Companion* and *Saturday Evening Post*. A big Thanksgiving and Christmas promotion is planned, with full-page two-color advertisements in *Saturday Evening Post* as the climax.

All of the materials for these five programs are now available for distribution. Requests should be sent to The Modern Kitchen Bureau, 420 Lexington Avenue, New York, N. Y.

CONVENTIONS AND MEETINGS

AUGUST

21-25 Illuminating Engineering Society, Hotel Fairmont, San Francisco, Cal.
22-25 National Association of Railroad and Utilities Commissioners, Seattle, Wash.
25-26 Maryland Utilities Association, George Washington Hotel, Ocean City, Md.

SEPTEMBER

6-8 Pennsylvania Electric Association, Bedford Springs Hotel, Bedford Springs, Pa.
7-9 Rocky Mountain Electric League, Estes Park, Colo.
20 General Sales Committee, EEI Headquarters, New York, N. Y.
21-22 Rural Sales Conference, Hay Loft, Electrified Farm, World's Fair, N. Y.
21-22 Wisconsin Utilities Association, Accounting Section, Plankington Hotel, Milwaukee, Wis.
28-30 Indiana Electric Association, French Lick Springs, Ind.

OCTOBER

2-3 Prime Movers Committee, EEI, 420 Lexington Avenue, New York, N. Y.
2-6 National Restaurant Association, Chicago, Ill.
5 Third Annual Conference, Commercial Electric Cooking Council, Chicago, Ill.
9-10 Electrical Equipment Committee, E. E. I., New Ocean House, Swampscott, Mass.
9-12 American Gas Association, New York City, N. Y.
9-12 National Electrical Contractors Association, Bellevue-Stratford Hotel, Philadelphia, Pa.
10-11 Transmission and Distribution Committee, EEI, New Ocean House, Swampscott, Mass.
16-20 National Safety Council, Atlantic City, N. J.
19-20 Empire State Gas and Electric Association, Westchester Country Club, Westchester, N. Y.
23-27 National Electrical Manufacturers Association, Palmer House, Chicago, Ill.

NOVEMBER

6-7 Wisconsin Utilities Association, Electric, Commercial and Technical Divisions, Schroeder Hotel, Milwaukee, Wis.
13-15 Third National Accounting Conference, Edgewater Beach Hotel, Chicago, Ill.

DECEMBER

4-5 Prime Movers Committee, EEI, Philadelphia, Pa.
4-9 American Society of Mechanical Engineers, Philadelphia, Pa.

FEBRUARY

5-6 Prime Movers Committee, EEI, Detroit, Mich.

Effect of Temperature

(*Continued from page* 418)

constituent than the 425° F. valve. Figure 7 shows the eutectoid to be not only especially prominent at the grain boundaries but also more extensive and interconnected in the high tin areas between the branches of the dendrites.

The micrographs clearly show the effect of prolonged exposure throughout the temperature range from 100 to 700° F. on the formation of eutectoid, to which the brittleness of the material is attributed. It is concluded from this investigation that bronze is affected in its structural and physical properties by exposure to elevated temperatures. The influence of the time factor on bronze should be given consideration in establishing a safe limit for tin content of bronze to be used at various temperatures.

LITERATURE CITED

1. American Society for Testing Materials, Standards, *18*, 447 (1918).
2. Ibid., *36*, Pt. I, 547 (1936).
3. Ibid., *36*, Pt. I, 551 (1936).
4. Bolton, J. W., Am. Soc. Testing Materials, Proc. *35*, Pt. II, 204 (1935).

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